

Climate change, water resources and WASH

A scoping study

Roger Calow, Helen Bonsor, Lindsey Jones,
Simon O'Meally, Alan MacDonald, Nanki Kaur

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Results of ODI research presented
in preliminary form for discussion
and critical comment

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Abbreviations

ADAPT	Assessment & Design for Adaptation to Climate Change – A Prototype Tool
AOGCM	Atmosphere-Ocean General Circulation Model
APF	Adaptation policy framework
AWG-LCA	Ad Hoc Working Group on Long Term Cooperative Action
BAP	Bali Action Plan
CBA	Community-based adaptation
CBOs	Community-based organisations
CC	Climate change
CDMP	Country Disaster Management Programme
CO ₂	Carbon dioxide
CoP	Conference of Parties
CRiSTAL	Community-Based Risk Screening Tool – Adaptation and Livelihoods
CRM	Climate risk management
CV	Climate variability
DfID	UK Department for International Development
EBA	Ecosystem-based adaptation
GCM	Global Climate Model
GEF	Global Environment Facility
GHG	Greenhouse gas
GtC	Gigatons of carbon
IPCC	Intergovernmental Panel on Climate Change
IWRM	Integrated Water Resource Management
LDC	Least Developed Countries
LLGHG	Long-lived Greenhouse Gas
MA	Millennium Ecosystem Assessment
mbgl	Miles below ground level
M&E	Monitoring and evaluation
NC	National Communications
NAPCC	The National Action Plan on Climate Change
NAPA	National Adaptation Programme of Action
NDF	National Disaster Framework (India)
NGO	Non-Governmental Organizations
NWP	Nairobi Work Programme on Impacts, Vulnerability and Adaptation to Climate Change
ORCHID	Opportunities & Risks from Climate Change and Disasters
ppm	Parts per million
SBI	Subsidiary Body on Implementation
SBSTA	Subsidiary Body on Scientific and Technological Advice
SLE	Sea Level equivalent
SLF	Sustainable Livelihoods Framework
SSA	Sub-Saharan Africa
SST	Sea Surface Temperatures
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
VA	Vulnerability assessment
VRA	Vulnerability reduction assessment
WASH	Water, sanitation and hygiene
WELS	Water Economy for Livelihoods (an analytical tool)
WRM	Water resources management
WUA	Water user association

Executive summary

Water is predicted to be the primary medium through which early climate change impacts will be felt by people, ecosystems and economies. Both observational records and climate projections provide strong evidence that freshwater resources are vulnerable, and have the potential to be strongly impacted. However, impacts on water resources and water-dependent services have yet to be adequately addressed in either scientific analyses or water policy.

This report aims to fill in some of the gaps. No new research is presented; rather the aim is to pull together what we know about the links between climate change and water, drawing on both the scientific and non-scientific literature, for an informed but non-specialist audience. Commissioned by WaterAid in the UK, the report has two broad objectives:

- To summarise current understanding of climate change projections and scenarios, and the impacts climate change may have on water resources, and water supply, sanitation and hygiene (WASH) in Sub-Saharan Africa (SSA) and South Asia.
- To discuss implications of the above for policy and practice at a range of different levels – from funding for climate change adaptation at an international level, to the planning and implementation of WASH interventions at a community level.

It is important to note the marked absence of literature on climate change and sanitation. As such, this report has largely focused on water resources and water supply. A key conclusion is that more research is required to better understand the impacts of climate change on existing sanitation systems and to identify effective responses to current and future climate change.

The report is intended for a broad range of decision-makers in government, the donor community, civil society organisations and the private sector. It is split into four sections as follows:

Section 1 provides a summary of observations of recent changes in water-related variables and describes the projections of future changes on water resources. It describes the different scenarios for predicting future climate change, the global and regional climate change projections with an emphasis on SSA and South Asia, predictions of climate change impacts on surface water and groundwater, and current scientific uncertainties and data gaps.

Section 2 builds on the discussion in Section 1 and focuses on climate change impacts on water availability, water quality and water infrastructure. The section also attempts to put climate change in context, highlighting other drivers of change that will affect the supply of water, the demand for water, or both.

Section 3 discusses policy responses to address climate change impacts at different levels. The section discusses climate change policy responses at the international and national level and provides an overview of current and emerging approaches to adaptation planning.

Section 4 documents how some of the adaptation policy responses and approaches discussed in Section 3 have been piloted and implemented. Specifically, it evaluates how pro-poor adaptation in the water sector is, and could be, integrated into programme and project planning. It provides an overview of the major toolkits and lessons learned, to date, in relation to climate screening, climate mainstreaming, community-level adaptation, and monitoring and evaluation.

Section 5 provides a summary of the above and outlines recommendations for planning and implementing WASH interventions that are resilient to climate change.

The key messages of the report can be distilled into three main areas:

1. Climate change impacts on water variables and implications for WASH

- There is *large uncertainty with respect to climate change predictions and impacts* on future water availability and quality in SSA and South Asia. Global warming is projected to cause an intensification of present climatic and hydrological variability in Africa and South Asia and

may cause extreme events – such as tropical storms, floods and drought – to increase in frequency and intensity.

- In terms of *water availability*, projected effects include: more seasonal and higher intensity rainfall; increasing seasonality of river flows; modification of groundwater recharge patterns; and risk of significant reduction in the volume of reliable surface water resources. Implications include reductions in the reliability of rainwater harvesting schemes; greater need for and reliance on both natural and man-made water storage; the potential breaching of (and damage to) low capacity sewage and drainage systems; and increased dependence on groundwater in Africa and South Asia to meet future water demand.
- In terms of *water quality*, climate change is likely to exacerbate existing problems. More intense rainfall events will result in increased turbidity of surface water as well as higher (seasonal) contaminant loading of shallow groundwater, possibly leading to an increase in water-borne disease. Increased flooding may also overwhelm currently used sanitary protection measures leading to damage of infrastructure and water contamination. In coastal areas there is likely to be significant incursion of salt water into aquifers as sea-levels rise.
- Climate change will put a premium on *information about water resources*, yet few countries know about the quantity, quality, distribution and reliability of their water resources, about how they are being used, or which water sources are functional. Monitoring systems need to be strengthened as a matter of priority, particularly for groundwater resources.
- *Climate change is one of a number of pressures on water and livelihoods*. In many countries, there are multiple, inter-related pressures, including demographic shifts, urbanisation, changing patterns and levels of consumption, and pollution - drivers of change that will affect the supply of water, the demand for water, or both. These other drivers may pose bigger threats to water resources and water-dependent services than climate change, at least over the short-medium term.
- *Water scarcity is not physically determined; access, entitlements and equity also matter*. Conventional notions of scarcity that focus on water availability, privileged in current climate change debates, sideline crucial supply-side issues of rainfall variability and water distribution and, on the demand-side, downplay the importance of access and equity. The water 'crisis' is a crisis for the poor, with its roots in politics and institutions, rather than water availability. Hence extending access to reliable and affordable water and sanitation services remains key to strengthening livelihoods and building resilience to climate change.
- Re-focussing the debate on *water security* offers a way forward, emphasising the importance of resource access and entitlements as well as water availability, quality, distribution and reliability. Water security can be defined as the *availability of, and access to, water sufficient in quantity and quality to meet the production, livelihood and health needs of populations, together with an acceptable level of water-related risk*.

2. Policy responses and policy engagement

- Adaptation to the impacts of current and future climate change is unavoidable, whether planned or unplanned. *Adaptation is now viewed as an essential component of any climate change policy*. Arguments now focus on which countries need to adapt, which sectors/areas/groups are most vulnerable, how best to provide support, and the level and type of finance required.
- *Adaptation* aimed at enhancing the capacity of systems to respond and adapt to climate change will require greater efforts to address the underlying causes of vulnerability and longer term planning beyond 'immediate needs'. Promoting flexible forward-looking decision making and governance is needed to reduce the risks of mal-adaptation.
- At a *global level*, the policy response to adaptation is primarily being carried out under the United Nations Framework Convention on Climate Change (UNFCCC). Planning focuses on

three issue-areas: Developing a Shared Vision on Adaptation; Identifying means to Implement Adaptation; and Enhancing Financial and Technical Support for Adaptation.

- At a *national level*, government responses have centred on the creation of National Adaptation Programmes of Action (NAPAs) and reporting actions through National Communications. NAPAs focus on: assessing vulnerability to climate change; identifying adaptation strategies; and identifying means to implement adaptation strategies – typically project based. While the process of NAPA preparation has generally been successful in raising awareness of climate change and encouraging dialogue, adaptation plans have not been mainstreamed into broader development policies, including poverty reduction strategies and water resources management. Nonetheless, most NAPAs identify water as a vulnerable ‘sector’, and attach importance to water-related adaptation.
- A number of approaches, including *vulnerability assessment, scenario-based planning, adaptive management, mainstreaming and community and ecosystem based management*, have been developed to facilitate the adaptation planning and implementation process. However, the value-added of ‘new’ approaches is sometimes questionable: the most effective form of adaptation will remain robust, climate-resilient development.
- Stakeholders can engage with the adaptation planning process at global, national and local levels. Areas of *engagement* include: feeding into vulnerability, hazard and adaptation assessments to fill existing knowledge gaps; disseminating climate related knowledge (on impacts and adaptation options) to local and national levels to facilitate the decision-making process; and climate-proofing ongoing and future programmes and projects.

3. Operational responses and pro-poor adaptation

- Both *WASH and water resources management investments can be ‘screened’ for climate risks* using the toolkits described in this report. Screening aims to: ascertain the extent to which existing development projects consider climate risks; identify strategies for incorporating climate change into projects; and guide project managers towards risk-minimising options. A major challenge is to ensure that a ‘top-down’ approach is combined with ‘bottom-up’ inputs. An aggravating circumstance in most countries is also the gap in knowledge in terms of both observational data and in understanding how climate change will affect the hydrological cycle and water-dependent services at the temporal and spatial scales relevant to decision making.
- To promote *pro-poor* adaptation, existing approaches such as *Water Safety Planning* could be extended to include screening for climate change risks and impacts. New frameworks have also been developed such as CRISTAL, a community-based screening toolkit. Drawing on a Sustainable Livelihoods Framework (SLF), it aims to help users understand links between livelihoods and climate and to assess a project’s impact on community adaptive capacity. This toolkit could potentially be applied to water resources management (WRM) interventions, but further analysis and field-testing is required to determine its effectiveness. In view of the ‘data gap’ in most developing countries and difficulties in downscaling climate projections at the basin scale and below, scenario-based approaches which consider a range of different climate futures are recommended.
- Lessons have been learned from implementing *community-level adaptation projects*. These include: the need for a wide-reaching communication strategy; the need for interventions that build on existing coping strategies; the importance of broad-based livelihood improvement and vulnerability reduction; and the importance of national and local ‘political’ support. *Equity issues* – the distribution of climate change costs and the benefits arising from planned adaptation interventions - have only been patchily integrated into project design thus far.
- Given the uncertainties surrounding the impacts of climate change on water, planning around *technology choice* should be ‘robust of uncertainty’, i.e. appropriate to a range of different rainfall and runoff conditions. This implies a greater focus on the reliability of different sources, for example siting boreholes and deeper wells in more productive aquifers, favouring

development of larger springs, and the strengthening of sanitary protection measures. However, the use of more vulnerable sources, such as shallow wells, should not be ruled out completely, especially in combination with other technologies that, collectively, spread risk and provide water for different uses.

1 Climate change scenarios

1.1 Introduction

Warming of the climate system is unequivocal, with significant increases of global mean air temperature ($\sim +1^{\circ}\text{C}$), sea surface temperature ($\sim +1^{\circ}\text{C}$) and sea level rise ($\sim +150\text{ mm}$) since 1960 (Pachauri and Reisinger 2007). Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the recorded increase in anthropogenic greenhouse gas (GHG) concentrations, leading to discernable impacts on other aspects of climate, and on physical and economic systems (*ibid*). Continued population growth and increased global economic development is likely to increase GHG emissions further, with the result that climate change will occur at a faster rate over the next 50 years (*ibid*).

Future GHG emissions are the product of very complex dynamic systems, and their future evolution is highly uncertain. Scenarios are alternative images of how the future might unfold and can be used as a tool to analyse how driving forces may influence future emission outcomes and to assess the associated uncertainties. The possibility that any single emissions path will occur as described in scenarios is highly uncertain. This section provides a summary of the different scenarios for projecting potential future climate changes, the global and regional climate change projections with an emphasis on Africa and Asia, projections about possible impacts on surface and groundwater, and current scientific uncertainties and data gaps.

1.2 Overview of scenarios

To understand potential climate change impacts, the Intergovernmental Panel on Climate Change (IPCC) has developed a range of scenarios in the Fourth Assessment Report (known as the SRES scenarios) based on different assumptions of the main demographic, economic and technological driving forces of emissions within different possible pathways of global socio-economic development (Bates et al. 2008; Nakicenovic et al. 2000).

Six benchmark scenarios – A1F1, A1T, A1B, A2, B1 and B2 – are taken to be representative of the wide range of future world development pathways and resultant emissions, and also to encompass a significant proportion of the underlying uncertainties in the main driving forces of emissions – see Box 1.1 and Figure 1.1 (Nakicenovic et al. 2000).

Box 1.1: Outline of the main IPCC SRES scenarios and storylines

A1 scenario family: a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and rapid introduction of new and more efficient technologies.

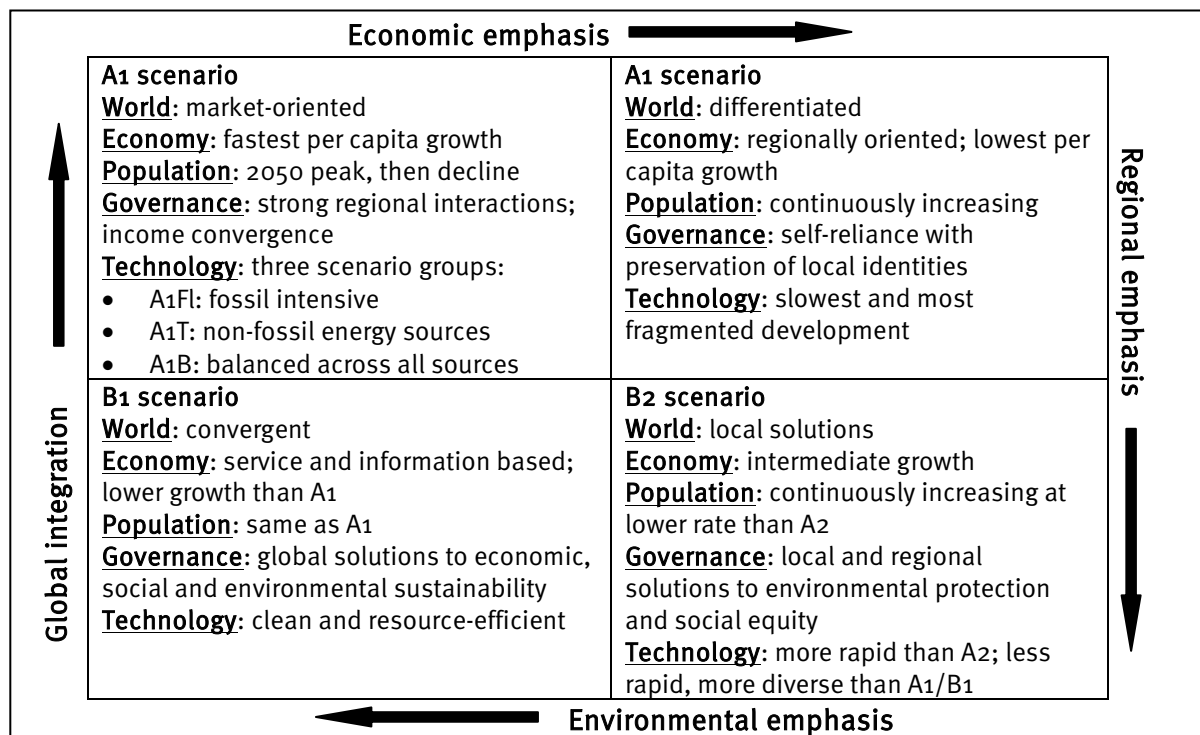
A2 scenario family: a very heterogeneous world with continuously increasing global population and regionally oriented economic growth that is more fragmented and slower than in other storylines.

B1 scenario family: a convergent world with the same global population as in the A1 storyline but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies.

B2 scenario family: a world in which the emphasis is on local solutions to economic, social, and environmental sustainability, with continuously increasing population (lower than A2) and intermediate economic development.

Source: Nakicenovic & Swart, 2000.

Figure 1.1: Key differences between the potential pathways of global socio-economic development



Between the scenarios, it is assumed that global population will have increased from 6.4 billion in 2000 to between 7.1 (B1) and 15.1 (A2) billion by 2100, gross world product will have increased either 10 or 26 fold, and total accumulative carbon loading from all sources will have increased from 100 Gigatons of Carbon (GtC) in 2000 to between 770 GtC and 2540 GtC in 2100 (Nakicenovic et al. 2000). The additional number of people projected to be living under high water stress varies from 1092 - 2761 million people in the A2 scenario, to 800 million people under the B2 scenario (Nakicenovic et al. 2000).

1.3 Overview of models and methods

The IPCC assessments of climate change are based on a range of Global Climate Models (GCMs) which are 'forced' by projected concentrations of long-lived GHGs (LLGHG) from the IPCC SRES emissions scenarios (Meehl et al. 2007; Randall et al. 2007). These models are focused on projecting the physical behaviour of the global climate system based on unmitigated emissions scenarios. The projections place little significance on ecosystem resilience or socio-economic adaptation to climate change. Derived models (e.g. hydrological models) then use the climate change projections to model second order impacts on ecosystems and the hydrological cycle at regional scales.

The most widely publicised IPCC projections are derived from Atmosphere-Ocean General Circulation Models (AOGCMs) forced by the A1B, B1 and A2 emissions scenarios (Meehl et al. 2007; Randall et al. 2007). These AOGCMs assess climate change on a 'global' to 'hundreds of kilometres' scale and include some important atmospheric and oceanic processes couplings. Since 2004 IPCC assessments have also been based on ensembles of GCMs. This approach improves the robustness of projections and has enabled quantification of the differences between separate climate models (Meehl et al. 2007).

A second generation of climate change models now exists, one of the most widely publicised of which is the Millennium Ecosystem Assessment (MA) (2004). In contrast to the IPCC projections, the MA projects climate change on a series of scenarios of socio-economic and ecosystem adaptation to a warming climate (Carpenter et al. 2005). As a result, the scenarios give a better insight into the likely impacts of climate change than that achieved by the IPCC scenarios, which place little emphasis on the adaptive capacity of ecosystems, or the ability of populations and ecosystems to access available resources such as water (Carpenter et al. 2005). However, with regard to predicting what physical

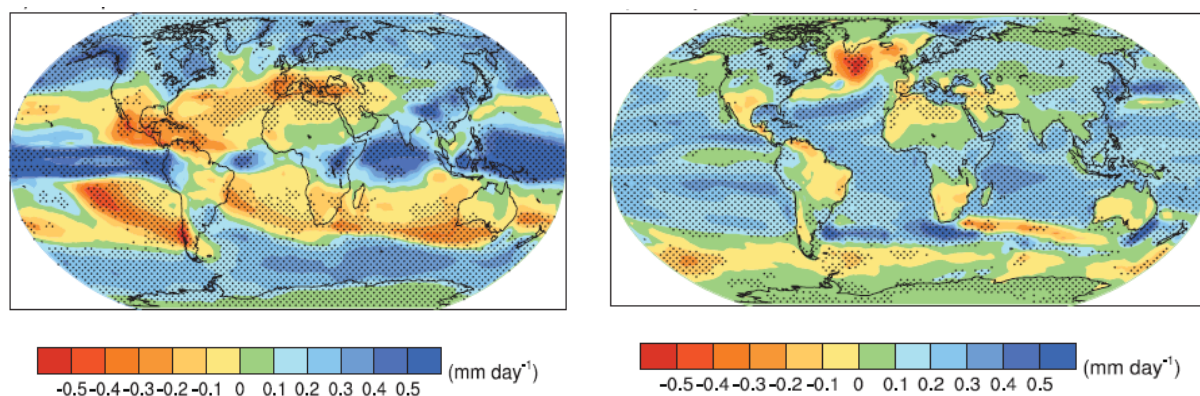
impacts can be expected in the future, it is unclear whether the IPCC or MA assessment has greater validity. Which assessment turns out to be closest to realised climate change depends largely on how much socio-economic mitigation and ecosystem adaptation actually occurs, yet this is very difficult to predict. The IPCC predictions, which place more emphasis on the physical causes of climate change than adaptive capacity, are inherently more pessimistic than the MA projections (Carpenter et al. 2005; Meehl et al. 2007). In view of the fact that present emissions are greater than those predicted by the A1F1 IPCC scenario since 2002, and reliance on a carbon economy has intensified rather than waned over the same time frame, the IPCC projections are currently a more appropriate indicator of present climate change. It is, however, invalid to extrapolate this conclusion to climate change prediction in 50 years time (Meehl et al. 2007).

1.4 Global projections

Projected climate change, both globally and within SSA and South Asia, represents an intensification of present climatic variability rather than a catastrophic change in the mean climate state. Best-estimate projections of changes to the mean global climate state indicate that average global temperature will increase by 1.8°C under scenario B1, to 4.0°C under scenario A1F1 (Parry et al. 2007) by 2090-2100, compared with the 1980-1999 baseline (Meehl et al. 2007). Warming over land will be greater than the global annual mean due to less water availability for evaporative cooling and the smaller thermal inertia of the atmosphere as compared to the oceans (Meehl et al. 2007). As a result of this feedback, plus changes to sea surface temperatures (SST), atmospheric circulation and land use patterns, the temperature rise over Africa for the same period is projected to be 3-4°C (roughly 1.5 times the global mean response), and for South Asia 3-5°C (Boko et al. 2007).

The anticipated rise in mean global temperature will result in many changes to the global climate system. Firstly, global sea-level is projected to rise by 0.18 m to 0.59 m due to thermal expansion alone under the B1 and A1F1 scenarios, respectively (Christensen et al. 2007). Thermal expansion of the oceans is projected to account for up to 70% of future sea-level rise. However, due to the exclusion of land ice mass loss within the IPCC projections, published values of sea-level rise do not represent the upper bounds of likely change (Meehl et al. 2007; Pachauri and Reisinger 2007). Current rates of land ice mass loss are best estimated at 0.77 ± 0.22 mm/yr sea-level equivalent (SLE), although this could increase significantly in the future. Work by Rahmstorf et al. (2007) which includes ice mass loss rates, based on observations over the last 40 years, suggests sea-level rise could be greater than one metre by 2100. Whilst future rates of ice mass loss are uncertain, based on recent observational evidence, and the most conservative IPCC scenario, it is predicted that the area flooded in Bangladesh will increase by at least 23–29% with a 2°C temperature rise (Mirza, 2003; Kundzewicz et al. 2007).

Figure 1.2: Likely change to precipitation (left) and evaporation (right) with projected climate change



*Stippled areas are the areas in which at least 80% of the GCMs agree.
Source: Meehl et al. 2007*

Warmer atmospheric conditions will cause intensification of the hydrological system. Precipitation is projected to be of much greater spatial and temporal variability, such that there will be, in general terms, a reduction of rainfall in the subtropics and an increase in rainfall at higher latitudes and in parts of the tropics (Boko et al. 2007) – Figure 1.2. Within all regions, a warmer climate will cause intensity of rainfall to increase and extreme events, such as tropical storms, floods and drought are projected to increase in both frequency and intensity (Meehl et al. 2007).

1.5 Regional projections

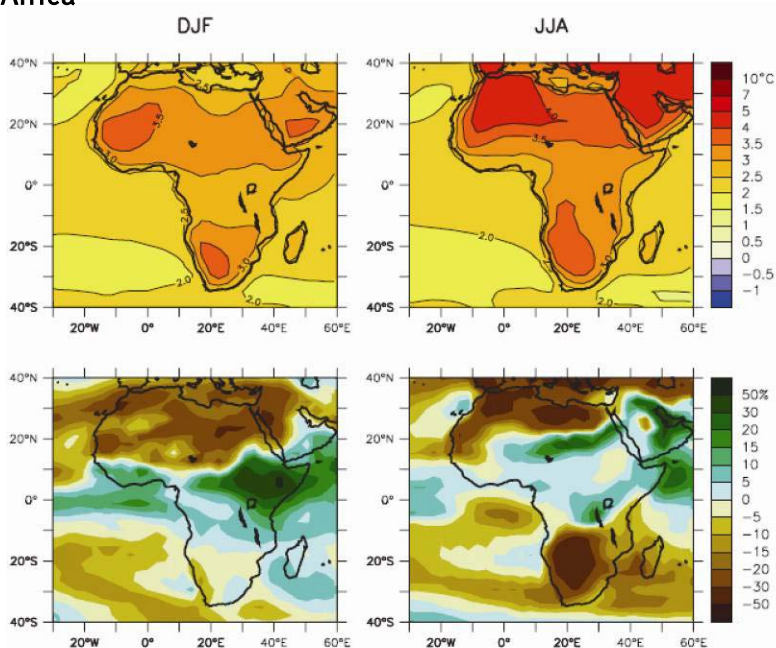
Within the subtropical climates of SSA and South Asia, rainfall patterns are presently dominated by the seasonal migration of the tropical rain belts. Small shifts in the position of these rain belts already result in large local changes in rainfall (Bates et al. 2008). As a result of this present variability, projections of climate change within Africa and Asia are highly uncertain and it is rare that more than 45% of the GCMs agree on what climate change can be expected (Christensen et al. 2007; Meehl et al. 2007).

Sub-Saharan Africa

Within Africa, GCMs driven by the SRES scenarios generally project rainfall to decrease by up to 20% in northern Africa, to decrease by up to 30% in southern Africa, and to increase by approximately 7% within central and eastern Africa – Figure 1.3 (Boko et al. 2007; Meehl et al. 2007). For the western Sahel (10-18°N, 17.5°W to 20°E), however, it is very uncertain how rainfall will evolve this century: some GCMs project a significant drying, whilst others simulate a progressive wetting with an expansion of vegetation into the Sahara (Boko et al. 2007). Moreover, recent studies (e.g. Funk et al. 2008) identify a tendency towards *lower* rainfall in the east, with reductions in the main growing season rainfall (March – May) across eastern Africa of around 15% associated with anthropogenic Indian Ocean warming.

More than half the projected reduction of rainfall in Africa occurs in the spring, due to the delay in the summer rainfall in the northern hemisphere (Boko et al. 2007). Country-level projections remain highly uncertain, however. The major challenges for simulating and predicting rainfall variability include the poorly understood, interacting roles of sea surface temperature, moisture sources, atmospheric particulates, land cover change and the El Nino Southern Oscillation. Given these uncertainties, the best guide to future change is probably to look at the recent past and assume a continuation of warming, persistence of significant rainfall trends and increases in rainfall variability.

Figure 1.3: Most likely temperature (upper) and precipitation (lower) changes modelled within Africa



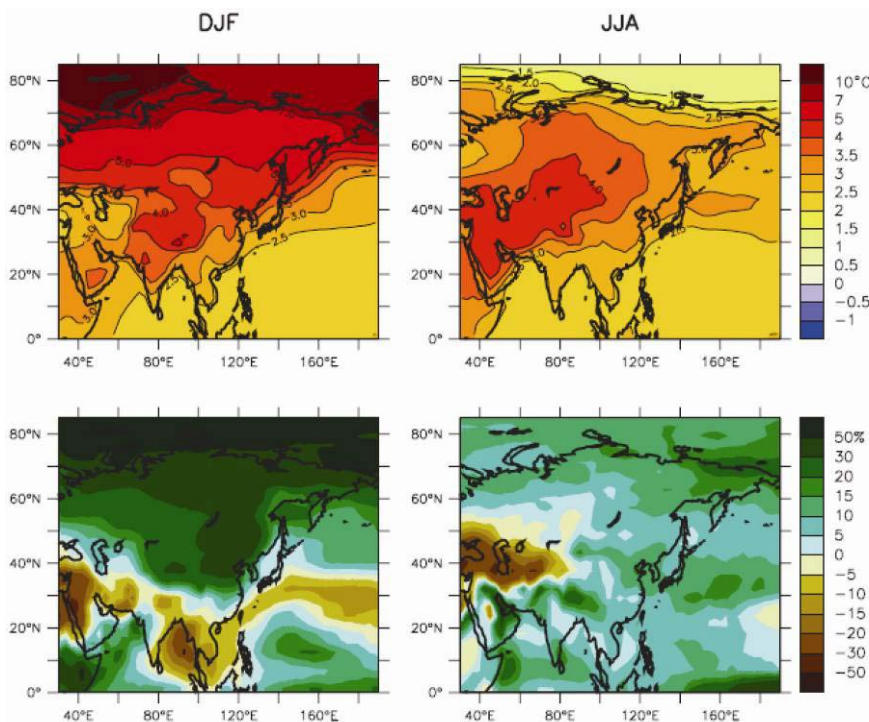
Source: Christensen et al. 2007

South Asia

Within South Asia, GCMs driven by the SRES scenarios generally indicate increased inter-annual variability in precipitation by 2100, with a 25% increase in precipitation within the Asian summer monsoon, but a decrease (by approximately 15%) in the winter months – Figure 1.4 (Cruz et al. 2007). Changes in precipitation over the Himalayas and other high altitude areas in Asia are less certain due to the inability of GCMs to simulate orographic rainfall. However, precipitation over the Himalayas is critical to the lowland hydrological systems across South Asia, both in terms of the timing and quantity of high altitude precipitation, and in terms of whether precipitation falls as snow or rain (Cruz et al. 2007).

An increased frequency and intensity of extreme weather events, including heatwaves and intense rainfall events, is projected in South Asia, East Asia and Southeast Asia. For example, a 10-20% increase in tropical cyclone intensity is projected for a 2–4°C increase in sea surface temperature (Cruz et al. 2007).

Figure 1.4: Most likely temperature (upper) and precipitation changes (lower) modelled within South Asia



Source: Christensen et al. 2007

1.6 Impacts on surface water runoff and river discharge

Of critical importance to the impact of future climate change in SSA and South Asia is the balance between increased precipitation (which is likely to be distributed in more intense and sporadic events), potential evaporation, vegetation, land use changes and soil moisture. Changes in river flows, as well as lake and wetland levels, will also depend crucially on whether precipitation falls as snow or rain (Bates et al. 2008).

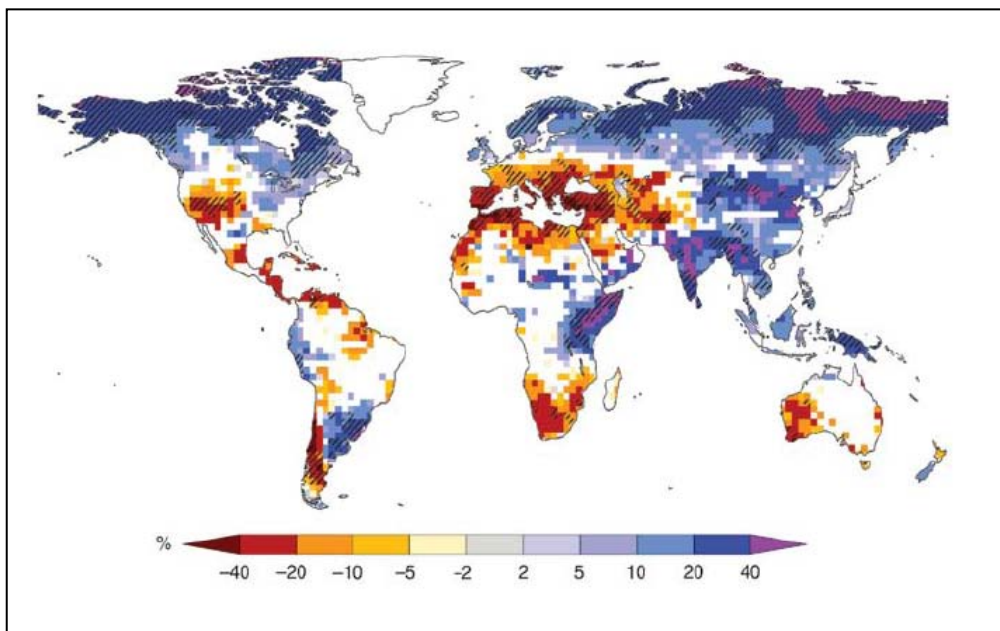
With higher temperatures, the water-holding capacity of the atmosphere increases and evaporative demand is projected to increase almost everywhere (Solomon et al. 2007; Meehl et al. 2007). Increases in global mean precipitation, brought about by more intense but sporadic rainfall events, is likely to be offset by the increased evaporative demand in many regions of South Asia and SSA, particularly where intense rainfall events with high runoff are interspersed with long dry periods of increased evaporation and evapotranspiration (Arnell 2003; Meehl et al. 2007). These projected conditions may lead to a greater risk of drying, land degradation, reduced groundwater recharge and a significant reduction in

the amount of available surface water resources, which are already seasonal (Feddema and Freire 2001; Foster et al. 2008; Solomon et al. 2007).

Changes in evapotranspiration will also tend to offset changes in precipitation and hence in regional water balances and runoff. However, the level of evapotranspiration expected with climate change is uncertain: although higher atmospheric carbon dioxide (CO₂) concentrations will reduce potential evapotranspiration, increased CO₂ concentration can lead to increased plant growth and thus leaf area, increasing evapotranspiration (Solomon et al. 2007). Hence overall changes in evapotranspiration demand also depend on the prevalent vegetation type and cover, and this is likely to change across SSA and South Asia as climate variability increases.

The complexity of the feedback processes outlined above makes it extremely difficult to predict outcomes in terms of the water balances of regional hydrological systems in SSA and South Asia. Figure 1.6 illustrates changes in annual runoff predicted by the GCMs, and highlights the huge areas where the direction of change, let alone its magnitude, remains uncertain.

Figure 1.5: Projected changes in annual runoff for 2090-2099 compared with 1980-1999



Source: Kundzewicz et al. 2007. Note: hatched areas and white areas show where GCMs agree or disagree, respectively, on the sign of change.

Nonetheless, some broad-brush estimates are possible. The current ‘best estimates’ of GCMs indicate there will be an overall reduction of river flows in South Asia of up to 20% by 2100 (Cruz et al. 2007; Bates et al. 2007). Because many of the rivers in South Asia are fed by glacial meltwater, this overall trend masks an initial increase in river flows as glaciers melt, followed by a reduction in flows as the ice mass gets smaller (Cruz et al. 2007; Bates et al. 2007). The relative contribution of each of these water sources to river flows in the long-term is highly uncertain and has been the subject of some debate.

Across Africa, the spatial and temporal distribution of future rainfall is poorly constrained by current GCMs and, as a result, future river flows are highly uncertain (Boko et al. 2007; Meehl et al. 2007). Uncertainty is greatest within SSA, where the sign of change with respect to river flow is largely unknown – Figure 1.5 (Boko et al. 2007; Meehl et al. 2007). In Africa, changes in river flow are much more dependent on changes in rainfall than temperature because of the absence of snow melt (Arnell 2003; Boko et al. 2007). In both SSA and South Asia, however, it is likely that the seasonality of runoff and river flow will increase (Arnell 2003; Cruz et al. 2007).

In both regions, it should be emphasised that separating the impacts of climate change on surface water runoff and river discharge from those related to non-climatic processes is extremely difficult.

River flows in the major basins of both Asia and SSA have been profoundly influenced by human activity, with major basin to basin variation in both key drivers of change and their impacts. However, it is clear that many current and future water problems have other causes (land use changes, clear cutting, demographic change, economic shifts, pollution), and climate change will superimpose itself on existing drivers.

1.7 Impacts on groundwater resources

One of the key uncertainties surrounding the impacts of a changing climate is the effect it will have on groundwater. The issue is of critical importance: in SSA alone, up to 80% of rural water supplies are thought to be dependent on groundwater, providing (largely) safe water for 400 million people. This dependence is likely to increase as surface water sources become increasingly seasonal, and demands from domestic, agricultural and industrial users for reliable water increase.

Groundwater storage comprises approximately 100 times the surface water storage and provides an important buffer against climate variability and change (MacDonald et al. 2011). Properly sited and constructed boreholes should continue to supply rural domestic demand, even with likely climate change. However, large abstractions for irrigation and town supplies will remain problematic.

Although groundwater systems are likely to respond more slowly to climate change than surface water systems, the impact of climate change on recharge, and hence longer-term availability, remains unclear (Kundewicz et al. 2007). Existing data on groundwater conditions and trends is extremely limited, and present quantities and patterns of recharge are uncertain. Moreover, long term projections of rainfall and temperature reveal little about how recharge may change. Hydraulically *effective* rainfall that contributes to groundwater recharge is affected as much by within-year rainfall variation, and the timing, intensity and duration of rainfall *events*, as it is by total seasonal or annual amounts.

1.8 Major uncertainties with climate change projections

There are major uncertainties in the present quantitative projections of climate change, and hence around impacts on water resources and supplies. Up to 90% of the current GCMs cannot accurately replicate past or present climatic conditions observed in SSA, suggesting that significant feedbacks between hydrological and climatic systems are not yet captured in the models (Meehl et al. 2007). The margin of error is often significant: in several GCMs precipitation - the key input to water systems - is overestimated across a wide area of SSA by more than 20%, and sea surface temperatures, which have a significant influence on rainfall patterns, are overestimated by 1-3°C (Meehl et al. 2007). As a result, for near-term projections of water resource change, climate model uncertainties (relating critically to precipitation) are the 'weak link', rather than the limitations of hydrological models or uncertainties in emission scenarios.

Climate model uncertainty is, at least in part, due to the exclusion of several key but poorly understood feedback processes within the global carbon cycle. Critically, standard GCMs model future climate change and the global carbon as uncoupled systems (Meehl et al. 2007). Under this assumption GCMs project the stabilisation levels of atmospheric CO₂ under the present A2 scenario to be 826 ppm by 2100. If CO₂ loading and the global carbon cycle are coupled, as modelled by the C⁴MIP GCM suite, then up to 1020 ppm atmospheric CO₂ is predicted by 2100, and CO₂ emissions need to be reduced well below year 2000 levels for stabilisation of atmospheric CO₂ to be achieved (Meehl et al. 2007). Coupling between climate change and carbon cycles is excluded in GCMs due to the poor understanding of processes driving land and ocean carbon uptake. For this reason, links between vegetation/land cover and climate are also excluded. However, these feedbacks are likely to have an important effect on climate through their influence on surface albedo, the ratio of latent heat and thus surface temperature, CO₂ emissions from vegetation changes and the capacity of land to adsorb CO₂ (Meehl et al. 2007).

A further weakness in linking GCMs with hydrological processes is the exclusion of daily and inter-annual climatic variability within GCMs, and the discrepancy of spatial scales between GCMs (typically a few hundred km) and hydrological processes. Downscaling techniques are used to help include daily variability within GCMs and to help quantify the relative significance of different sources of uncertainty affecting water resource projections (Meehl et al. 2007). However, even if GCMs and hydrological

models were of a comparable resolution, the exclusion of key physical feedback processes within the GCMs means makes the prediction of water resource futures extremely difficult. Using multi-ensemble runs of models (the use of numerous runs from different GCMs with different model parameters) is difficult when undertaking an impact on freshwater resources and the scenarios rarely reproduce observed climate with any accuracy.

1.9 Climate science since the IPCC Fourth Assessment: 4°C possibilities

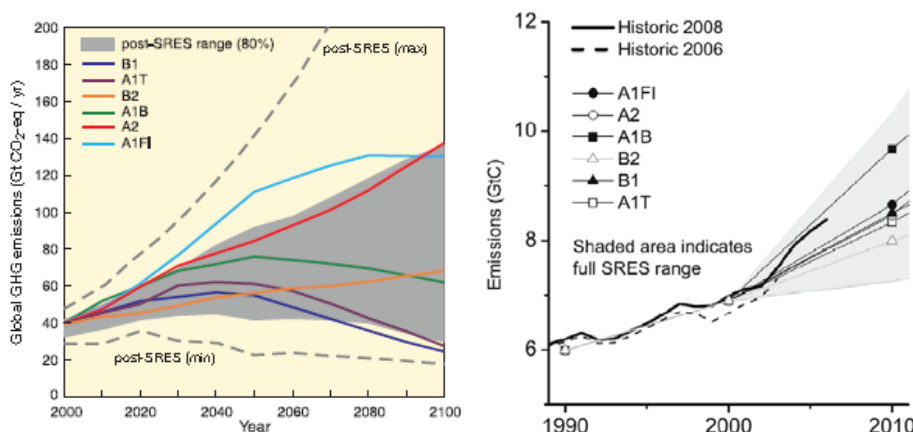
Although the IPCC Fourth Assessment is still regarded as the authoritative work on climate change, observed data since 2000 indicate that the IPCC SRES scenarios of future emissions and ‘likely’ climate change are conservative (Meinshausen et al. 2009; Richardson et al. 2009). The Fourth Assessment Report concluded that a mean global temperature rise of 1.8 °C was most likely, but population growth, intensification of economic globalisation and a failure to decarbonise global energy sources has meant fossil-fuel emissions have consistently matched those predicted by the ‘worst-case’ (A1F1) scenario of the Fourth Assessment – Figure 1.6 (Raupach et al. 2007; Pachauri and Reisinger 2007; Van Vuuren and Riahi 2008).

Since 2000, fossil fuel emissions have increased at a rate of 3.4%/year, compared with just 1.0%/year in the 1990s (Le Quéré et al. 2009). Key climatic indicators, such as the rate of ice-sheet melt and global ocean temperature, have exceeded those predicted to be likely, and sea-level is now expected to rise by more than 1 m by 2100 due to thermal expansion alone (0.5 m more than that predicted by the IPCC in 2007), and by up to a further metre due to current rates of melting of the Arctic and Greenland ice sheets (Richardson et al. 2009). There is also evidence to suggest that the land and ocean sinks of atmospheric CO₂ are becoming weakened and not keeping up with current increases in CO₂ emissions (Friedlingstein et al. 2006; Le Quéré et al. 2009). A weakening of CO₂ sinks could lead to much greater warming from emission increases than observed at present (Le Quéré et al. 2009).

Based on observational evidence since 2000, an emerging consensus is that a global mean temperature rise of 2.4 °C is likely, regardless of any emissions cuts, and that a global mean temperature rise of 4 °C by 2100 is more likely than not (Ramanathan and Feng 2008; Van Vuuren and Riahi 2008; Le Quéré et al. 2009; Richardson et al. 2009). Recent modelling work using the HadCAM GCM suite suggests a 4 °C rise in global mean temperature would result in a rise in near-surface temperatures in Africa of between 5.0 to 7.5 °C by 2100 (Arnell 2006; Van Vuuren et al. 2008). Such a strong warming of the atmosphere would have a significant impact on processes in the hydrological system (Meehl, et al. 2007) and it is increasingly thought that we need to prepare for greater climatic uncertainty, based on a 4 °C rise in global mean temperature. In response the Fifth Assessment, due to be published by the IPCC in 2013, will be based on a revised set of emissions scenarios which will include a wider range of possible future emissions (Van Vuuren et al. 2009). The scenarios will also be generated using a more cause-and-effect approach, to enable better simulation of the feedbacks between increased emissions, potential climate change and adaptation (Van Vuuren et al. 2009).

Following on from this, predictions of water stress within the IPCC Fourth Assessment could be viewed as conservative (Vorosmarty et al. 2000; Arnell 2004; Kundzewicz et al. 2007), though as we make clear in the following sections, indicators of water stress or scarcity need to be viewed with caution.

Figure 1.6: Illustration of projected increases to CO₂ emissions under the IPCC scenarios (left) and the actual emission trajectory, followed since 2000 when the IPCC scenarios were devised (right)



The present emission trajectory exceeds the 'worst-case' A1F1 IPCC scenario. Source: VanVuuren and Riahi 2008

1.10 Data gaps and needs

The most pressing data needs relate to groundwater resources and the climatic, and non-climatic, drivers of quantity and quality change. Research efforts in Africa and Asia have been *ad hoc* and sporadic to date, with little collation of datasets, or systematic monitoring of resource conditions, patterns of use and system performance over time (Adelena and MacDonald 2008).

There is a clear need for long-term monitoring of both river and groundwater levels in SSA and South Asia to better understand resource conditions and links with climate (*ibid*). Information on land-use change and its impact on recharge rates is also critical. A key challenge is to devise decision-support systems that include monitoring and forecasting of climate and non-climate drivers, indicating the envelope of potential impacts and planned actions, rather than isolated monitoring systems divorced from end users.



1.11 Key messages

Models and methods

- The IPCC assessments of climate change are based on a range of Global Climate Models (GCMs), which are forced by predicted concentrations of long-lived GHGs (LLGHG) from the IPCC emissions scenarios.
- GCMs cannot accurately replicate past and present climate variability in SSA and South Asia, due to the exclusion of several key, but poorly understood, feedback processes within the global carbon cycle. There is therefore large uncertainty in the climate change projections for SSA and South Asia, particularly for rainfall, and even greater uncertainty within derived hydrological models that attempt to predict runoff and recharge. However, there are some areas where the regional impacts can be stated with a high degree of confidence (IPCC 2007).

Projections

- The IPCC climate change assessment is the most valid to date, but it is increasingly thought to be conservative, with present GHG emissions having been higher than those predicted by the worse

case IPCC scenario (A1F1) since 2002, and ice melt occurring much faster than predicted. There is now an emerging view that we are committed to a global mean temperature rise of +2.4°C, regardless of any future emissions cuts, and that adaptation should now be based on a +4°C rise in global mean temperature (Le Quéré et al. 2009; Richardson et al. 2009).

- It follows that IPCC assessments of future water stress may also be conservative. However, IPCC assessments are based on the physical availability of water and do not consider ‘economic’ water scarcity or groundwater storage. In this report, we contend that accessibility of available water, and not just the total annual water availability within a country should be considered.
- It is highly likely that by 2100 near-surface temperatures will be 3-4°C and 3-5°C higher over SSA and South Asia, respectively. Even under the most conservative climate change prediction, sea-level rise will probably result in flood risk in 23-39% of Bangladesh by 2099.
- Global warming will cause an intensification of present climate variability in SSA and South Asia, but it is uncertain what the net effect of climate change will be on the water balance of major river basins.
- Increased seasonality of surface water sources will increase dependence on (less vulnerable) groundwater in SSA and South Asia to meet future domestic, agricultural and industrial water demands. Although groundwater is likely to be of slower response to projected climate change than surface water, the effect of increased hydrological and climate variability on groundwater recharge and groundwater systems is still very unclear.
- It is increasingly thought that we need to prepare for greater climatic uncertainty. In response, the Fifth Assessment of climate change by the IPCC, due to be published in 2013, is to be based on a revised set of emissions scenarios (RCPs – Responsive Concentration Pathways). The scenarios will include a wider range of possible future emissions, and some simulation of feedback between increased emissions, potential climate change and adaptation (Van Vuuren et al. 2009).

Data gaps and needs

- While there is good confidence in the trajectory of continental and regional temperature, the extent to which current regional models can successfully downscale precipitation is unclear. Downscaling to the level of large river basins with current circulation models may produce more hydrological ‘noise’ rather than clear insight, especially given the large impact of baseline socio-economic assumptions.
- There are therefore critical data gaps with respect to the impacts of climate change on water, and particularly on water quality, aquatic ecosystems and groundwater conditions. In addition, data on the distributional impacts of climate change on different users, particularly the poor, are inadequate. Problems are compounded by the lack of existing monitoring information on water resource conditions and patterns of use, particularly for groundwater.

2 Climate change impacts and risks

2.1 Introduction

There is significant pressure from politicians and public to make confident predictions about the impacts of climate change on mankind. This is increasingly the case in the water sector, fed by alarmist journalism suggesting that water supplies will fail in many areas. As noted in Section 1, however, such predictions about impacts on water resources, and water-dependent services, are difficult to make at a basin scale. This high level of uncertainty means that *confidently predicting* effects on WASH services in a particular country is unwise.

In this section we discuss the *potential* impacts of climate change on WASH, focussing in particular on South Asia and SSA. We use an approach that goes some way beyond questions of water availability and quality to look at issues around access and use. Taken together, these factors determine the scarcity, or water (in)security, experienced by local populations (MacDonald and Calow 2007; Calow et al. 2010). In addition, we look at the climate resilience of different WASH technologies, building on the work of Howard et al. (2010).

2.2 Changes in water quantity and implications for WASH

Existing climate variability

Surface water resources in Africa and South Asia are already strongly seasonal as a result of present climate variability. Variability in river flow is marked (see Figure 2.1 below) due to the migration of tropical rain belts in Africa and spring snowmelt in central Asia (Hulme 2001; Held et al. 2005; Tilahun 2006). Figure 2.2 illustrates the length of the dry season across the world, highlighting differences between wealthier and poorer countries.

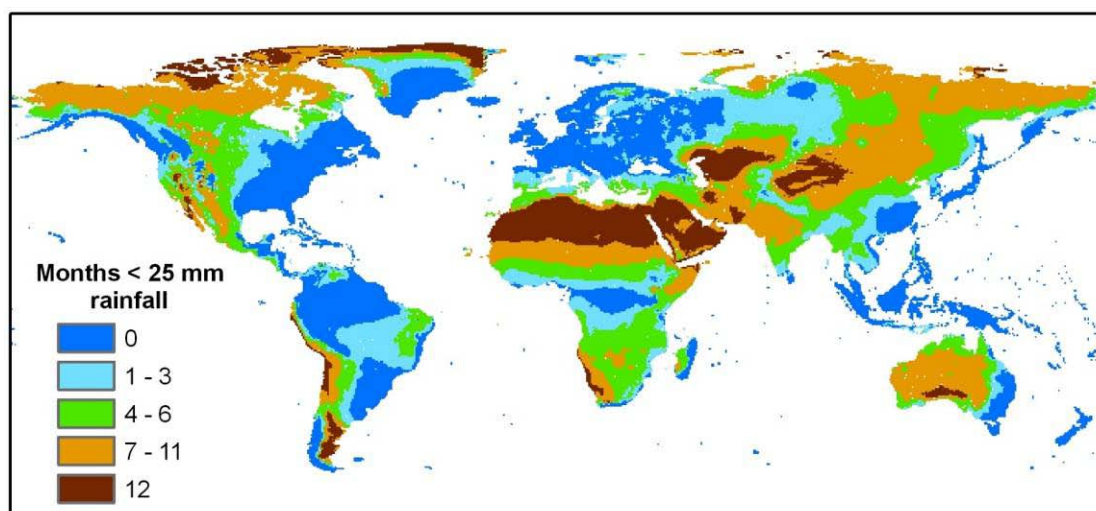
Superimposed on this seasonal variation are ‘natural’ variations; droughts and floods are already part of the existing climate variability experienced across the world (e.g. Verschuren et al. 2000). Soil moisture and small streams are most vulnerable to these changes, whereas deep groundwater drawing on many years’ recharge is largely isolated from short-term fluctuations. Between these two extremes, larger rivers, lakes, and shallow groundwater can all be vulnerable to changes in climate, depending on local circumstances.

Figure 2.1: Strong variability to surface water availability already exists within SSA



Difference in seasonal flow of River Oju, SE Nigeria: mid-wet season (left), mid dry season 4 months later (right). Photos © NERC.

Figure 2.2: Length of dry seasons worldwide (1961-1996)



Source: Hunter et al. 2010. Calculated using statistics from New et al. 1999.

Predicted impacts of climate change

The impact of climate change on surface and ground waters will depend critically on how increased intensities of rainfall, and higher evaporative demands, translate to soil moisture and the volume, variability and seasonality of runoff.

Rainfall

Rainfall is predicted to become more seasonal, with prolonged dry periods between rainfall events. Individual rainfall events are also likely to be more intense (Kundewicz et al. 2007). More water is likely to be ‘lost’ as runoff, and there will be greater need to store water to mitigate these effects. Rainwater harvesting schemes may become less effective, as they are vulnerable to extended dry periods under existing climatic regimes. Overall, more reliance may need to be placed on water supply technologies which utilise a water store (e.g. groundwater or dams).

Increased intensity of rainfall will also pose a problem for drainage and sewerage disposal in urban and peri-urban areas. It is likely that low-capacity systems, or those that are in poor repair, will be overcome, leading to increased contamination (Hunter 2003). In rural areas, where on-site sanitation (or no sanitation) co-exist alongside groundwater wells, increased flooding may overwhelm currently used sanitary protection measures, leading to damage or destruction of infrastructure and gross contamination.

Surface water resources

With increased intensity and irregularity of rainfall, the inter-annual variability of river flows is likely to increase, such that rivers will become increasingly ‘flashy’ and seasonal. As a result, flood events will be more common, and an increased proportion of the available surface water will be lost in peak discharges, reducing the quantity of accessible water for WASH (Boko et al. 2007).

Long-term changes in surface water availability are more uncertain. By the end of the century, rivers in South Asia are likely to exhibit decreased summer flows (after an initial increase) and increased winter flows resulting from recession of the Himalayan ice mass in a warmer global climate (Cruz et al. 2007; Kundewicz et al. 2007). Glacial melt water presently contributes up to 70% of the dry season baseflow of the Indus, so glacial recession will have significant impacts on water availability for WASH in South Asia (Cruz et al. 2007). In addition, more winter precipitation is likely to fall as rain rather than snow, with the result that rivers in South Asia are likely to become more unreliable and more prone to flooding (Cruz et al. 2007). Shallow boreholes located on the floodplains of rivers in South Asia are therefore more likely to be contaminated from flood events more often (Cruz et al. 2007).

In Africa, long-term change to surface water availability is entirely dependent on how changes in rainfall patterns and increased evaporative demand translate to shifts in soil moisture deficits and surface water runoff (Boko et al. 2007; Kundewicz et al. 2007). At present, this is very difficult to predict.

Groundwater

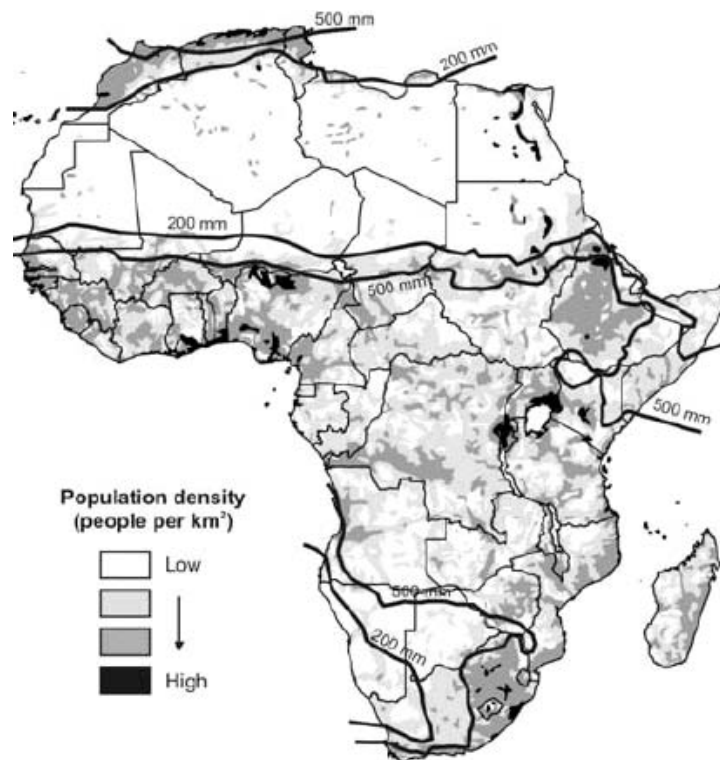
The potential impact of climate change on the availability of groundwater is poorly understood. This is partly because recharge processes are complex and poorly constrained – even without the complications of climate change (Döll and Fiedler 2008; Healy 2010). Many water supply services rely on groundwater, particularly in rural settings, so developing a better understanding of climate-groundwater links is vital (Calow and MacDonald 2009; Calow et al 2010).

Climate change is likely to modify groundwater recharge patterns, as changes in precipitation and evaporation translate directly to shifts in soil moisture deficits and surface water runoff (Foster et al. 2008). Increases in rainfall intensity and evaporative demand will, more likely than not, result in increased irregularity of groundwater recharge (Kundewicz et al. 2007). However, groundwater recharge will also be affected by soil degradation and vegetation changes, both of which may be affected by climate and human drivers (Solomon et al. 2007).

The resilience of groundwater to long-term (decadal) shifts in climate is governed by the available groundwater storage. Larger groundwater bodies contain groundwater storage several orders of magnitude greater than average annual recharge and will, therefore, respond very slowly to long-term changes (decadal) in recharge or short-term (inter-annual) shocks – for example the thick sandstone aquifers in northern Africa (MacDonald et al. 2011). Smaller groundwater bodies with lower storage will not be as resilient to long-term (decadal) changes in climate, but may recover quickly from drought if recharged regularly (MacDonald et al. 2009, 2011).

For many people the more important issue is the *resilience of the water supplies* dependent on groundwater, rather than the actual groundwater resource itself. Research from the behaviour of water sources during droughts has shown that: 1) improved sources are much more reliable than unimproved sources (Bonsor et al. 2010); and 2) boreholes in higher yielding (more permeable) aquifers are generally much more reliable than in lower yielding aquifers (MacDonald et al. 2009). These observations indicate that the permeability of aquifers should be considered alongside storage and long-term recharge to the aquifer when investigating the resilience of water sources to changes in climate. Work by MacDonald et al. 2011 in Africa has indicated that for much of Africa, carefully sited and well-constructed boreholes will be able to sustain rural domestic water demand even with predicted climate change. In some semi-arid and arid areas groundwater-levels may be below the depth at which the groundwater can be easily exploited, but these areas are generally less densely populated than wetter areas (MacDonald et al. 2011).

Figure 2.3: The main rainfall-recharge zones relative to the population density Africa



*Three broad rainfall-recharge zones in Africa: areas with < 200mm annual rainfall (no recharge), areas of 200-500mm annual rainfall (up to 25 mm of recharge) and areas in which annual rainfall is > 500mm (25-50mm of recharge).
Source: MacDonald et al. 2009*

Major uncertainties

- Large uncertainties exist as to how surface and ground waters respond to climatic changes. This is because of uncertainties in the rainfall projections of GCMs and the difficulty in quantifying effective rainfall with greater climatic variability. Whether there will be an increase or decrease in effective rainfall, with increased intensity and irregularity of rainfall and a higher evaporative demand, is still very unclear.
- A further key uncertainty relates to the partitioning of effective rainfall that can be expected within a climate of more intense rainfall events, higher evaporative demand and increased soil degradation. Whether degraded soils will facilitate increased groundwater recharge, or greater surface runoff, is critical to the partitioning of net rainfall in SSA and South Asia, but remains a key unknown. Whilst more intense rainfall can lead to increased groundwater recharge, particularly in semi-arid regions with permeable soils, it is also possible that increased temporal variability of rainfall will lead to greater soil crusting and soil degradation, such that overland flow increases and groundwater recharge decreases (Döll and Flöerke 2008).
- Data on groundwater conditions and responses to climate change, in terms of both quality and quantity, are lacking. Very few developing countries have groundwater monitoring systems in place (with the exception of India), and without the data these would provide, it is very difficult to calibrate existing models and make confident predictions about groundwater futures.

2.3 Changes in water quality and implications for WASH

Existing problems of water quality

Water quality is already under threat in SSA and South Asia as a result of poor sanitation (less than 70% of rural populations have access to proper sanitation) and intensive use of fertilisers (JMP 2008; Pritchard et al, 2008). In addition to this pathogenic and organic contamination, within urban and industrialised areas there is often inorganic contamination of water resources (Adelana et al. 2008; MacDonald et al. 2009).

Surface water and shallow groundwater quality is widely reported to deteriorate seasonally in SSA and South Asia (e.g. Godfrey et al. 2005; Pritchard et al. 2008). This is as a result of intense rainfall events during the wet season causing increased turbidity of the water (suspended solid content) and enabling higher concentrations of pathogens to be transported through the sub-surface (Hunter 2003; Taylor et al. 2009, Pritchard et al. 2008).

Vulnerability of shallow groundwater within the wet seasons of SSA and South Asia can be high due to the high permeability of lateritic soils and high groundwater levels (often <10 mbgl) (MacDonald et al. 2009). When the water table is elevated within the wet season, pathogens (and other suspended contaminants) can enter shallow groundwater directly from the base of latrines and other conduits, and travel up to 1 km within the shallow, subsurface whilst still virulent (Taylor et al. 2009, Pritchard et al. 2008).

Deeper groundwater, which is generally buffered from intense recharge events, is of much lower vulnerability to contamination and groundwater quality is generally good (MacDonald et al. 2005; Döll and Fiedler 2008). However, the natural baseline quality of deep groundwater cannot be guaranteed and, within some regions of South Asia and SSA, natural groundwater quality is poor. Within Bangladesh it is estimated 57 million people drink groundwater containing arsenic five times over the WHO organisation guideline value of 10µg/l (BGS, 2001a). And within the Ethiopian Rift, fluoride concentrations exceed WHO guideline values as a result of mixing between geothermal waters containing high fluoride and groundwater. Both dental and skeletal fluorosis is widely reported in the region (BGS, 2001b).

Predicted effects of climate change

Surface water and shallow groundwater resources

Climate change is likely to exacerbate existing water quality issues. More intense rainfall events and an increase in erosion may raise the turbidity of surface waters and result in a higher, seasonal organic and pathogenic contaminant loading of shallow groundwater bodies (Bates et al. 2007; Boko et al. 2007). Water-borne disease (e.g. cholera, diarrhoeal disease, dermatosis, cardiovascular disease and gastrointestinal disease) may therefore increase with climate change if soil contaminants are washed into surface water resources and shallow groundwater sources (Kundewicz et al. 2007; Pritchard et al. 2008).

There are undoubtedly clear links between access to safe, reliable water sources and human health which could be exacerbated by greater climate variability (Costello et al. 2009; Hunter et al. 2010). Increased flooding of latrines and unimproved sources could lead to a significant rise in diarrhoeal disease and infant mortality, and warmer water temperatures could lead to greater transmission of disease (*ibid*). Reduced functioning of water supplies during extended droughts could also increase the burden of disease as people use poorer quality, 'last resort' sources.

In regions where surface water and groundwater recharge are projected to decrease, general inorganic water quality may also decrease due to the lower dilution capacity of water resources (Kundewicz et al. 2007). Since predictions of future water quantities are so uncertain, however, it may be that recharge, and dilution, increases. In view of these uncertainties, action should focus on strengthening existing good practice and water safety planning, based on what has already been shown to reduce contamination of water sources (Taylor et al. 2009; Pritchard et al. 2008).

Groundwater resources

Climate change is likely to have a significant impact on the quality of groundwater in some regions. Greatest change is predicted in coastal aquifers, where it is very likely there will be significant incursion of salt water directly associated within sea-level rise (Kundewicz et al. 2007). India, China and Bangladesh are especially susceptible to ingress of saline sea water in coastal areas, as over-exploitation of groundwater has lowered groundwater levels, and within some parts of South Asia, the likely sea-level change of 0.4-1.0 m by 2100 could induce salt-water intrusions to ingress 1-3 km inland (Cruz et al. 2007). Increased evapotranspiration, is also predicted to lead to increased salinity of shallow groundwater inland (Kundewicz et al. 2007).

Major uncertainties

- Predictions of future water quality are even more uncertain than those for water availability. Key questions relate to the dilution capacity of surface water and groundwater resources, and whether these will increase or decrease with climate change.
- Depending on the realised partitioning of effective rainfall between surface water and groundwater, contaminant loading may be biased to one of these water resources. What partitioning can be expected under future climates is unknown.

2.4 Climate change in context

Separating the impacts of and responses to climate change from those related to socio-economic and demographic trends is not straightforward, particularly as autonomous adaptation is driven by all of these factors at the same time. Nonetheless, it is clear that climate change is one of a number of pressures on water resources, and that population growth, urbanisation, land use change and rising food demands will all have a major impact on both patterns and levels of water demand.

Take demographic change in Africa as an example. In contrast to knowledge of the direction and magnitude of hydrological changes under different climate scenarios, the prospects of demographic change in Africa in the 21st Century are known with some certainty (Carter et al. 2007). African population will grow by around 140% between 2000 and 2050, and it will become increasingly urban (by 320% over the same period). Overall water demand can therefore be expected to increase by at least 140% in the first half of the 21st century, and probably more as per capita demands rise. In Ethiopia, the population is expected to increase from 77 million in 2007 to around 146 million by 2050, an increase of almost 90%. The pressure on land and water this will generate will likely dwarf the impacts of climate change. Indeed on a global scale, the IPCC (Bates et al 2008) acknowledge the dominance of population growth as a key driver of change, at least to the 2050s.

Conversely, it is also clear that international and national projections of population, and water availability, tell us little about disparities in water distribution, access and control – factors that affect the scarcity experienced by local users and sectors, particularly the poor. The latest figures from WHO/UNICEF (2010), for example, indicate that the rural population without access to an improved drinking water source is over five times greater than that in urban areas, and that the richest quintile of the population in SSA is more than twice as likely as the poorest quintile to use an improved drinking water source. Hence access to water in most developing countries mirrors the distribution of wealth (UNDP 2006).

Scarcity, then, is not a natural phenomenon. Rather, water ‘crises’ are caused or exacerbated by struggles over access and control, institutional failures and inequalities of power and poverty (UNDP 2006; Mehta et al. 2007), and have little to do with the naturally available water resources of a country (Chenoweth 2008). Ethiopia, for example, has an abundance of renewable freshwater: 1900 m³ *per capita* is well above the commonly cited 1000 m³ *per capita* ‘scarcity’ threshold (World Bank 2006, citing figures for 2002). Yet government figures indicate that only 54% of rural people have access to improved supplies (GoE 2008).

Moreover, coverage figures routinely over-estimate access because they assume water supply infrastructure is fully functional. Recent figures compiled by the Rural Water Supply Network for 21 countries in SSA suggest that roughly 40% of handpumps are ‘non-functional’, representing a total investment of some US\$1.2 - \$1.5 billion over 20 years (RWSN 2010). The problem is not confined to SSA: Brikke and Bredero (2003) report that in most developing countries, some 30-60% of existing rural water supply schemes are inoperative at any given time.

To the above, we would add that in many of the poorest countries, particularly in SSA, coping with existing levels of climate variability is much more of a challenge than managing incremental and uncertain future change. Even in a *normal* year, roughly eight million Ethiopians require food aid, and roughly 250,000 children die from diseases related to poor water and sanitation. In this context, it is vital that donor perspectives do not lose sight of developing country realities: perhaps a preoccupation with future climate change is obscuring a more balanced appreciation of existing risks and vulnerabilities.

2.5 Technology choices

In most areas the key determinants of water security will continue to be access rather than water availability (Calow and MacDonald 2009). Extending access, and ensuring that targeting and technology decisions are informed by an understanding of groundwater conditions, will become increasingly important.

With extended dry periods, more intense rainfall and higher evaporative demand highly likely by 2050 (Meehl et al. 2007; Boko et al. 2007), it is increasingly important that development of water-supply technology now uses sources (e.g. deeper hand-wells and boreholes) which access natural water storage (MacDonald et al. 2009). Surface water and very shallow groundwater resources are likely to be more vulnerable to climate change. As a result, sources which exploit these resources require greater site investigation and built in redundancy to ensure they are sustainable. However, a much sharper appreciation of aquifer responses to changing climate, storage limits and demand pressures is needed if development of water-supplies in Africa and Asia is to be sustainable.

Table 2.1 below outlines the main technology choices available. The effects of predicted climate change in Africa and Asia for each technology is discussed, alongside possible mitigation measures.

Table 2.1: Technology choices for future water-supply in Africa and Asia

Technology	Description	Climate risks	Possible impacts	Responses
Rainwater harvesting	Rainwater collection and storage in tanks – household or community level	There may be fewer rainy days and longer drought periods. Rainfall events may be more intense	More storage may be required to bridge low rainfall periods. Danger of damage and contamination from flooding	Build in redundancy for potential reduced rainfall and longer dry seasons Ensure protection against flooding
Reticulated schemes from small rivers and dams	Pumped schemes to villages and small towns based on small dams or river abstraction	Changed seasonality of runoff, peak flows and sediment load	Lower and less certain flows. Possible increased sedimentation Dams may be filled with sediment – possibility of failure	Design to a higher capacity Build in mechanisms for dealing with increased sedimentation Conjunctive use of surface and groundwater to increase adaptability to change.
Shallow family wells	Wells less than 10 m deep – dug by hand and often unlined	More intense rainfall, longer dry season	Increased contamination of sources More likely that sources will fail	Should generally not be promoted in isolation as improved water supplies
Improved hand dug wells	Hand dug wells often > 10 m deep lined with concrete and capped at the surface	More intense rainfall, longer dry season	Increased risk of contamination More likely that sources will fail	Hand dug wells should be tested at the peak of a normal dry season. They should be sited in productive parts of the aquifer and deep enough to intersect groundwater below 10 m There should be an emphasis on casing out shallow layers and runoff
Protected spring supplies	Perennial springs where the source is protected and piped to a standpipe	Longer dry season – more intense rainfall	Possibility of contamination – particularly in urban or peri-urban settings Springs may be less reliable in longer dry seasons	More thorough investigation of seasonal spring flow and contamination pressures in catchment. Build in greater redundancy

Technology	Description	Climate risks	Possible impacts	Responses
Boreholes	Boreholes, 20-60 m deep, with hand-pump mechanism to abstract water	Longer dry season – more intense rainfall	Higher demand in extended dry seasons may cause source failure, and in some cases depletion of water resource. High demand can lead to mechanical failure. Risk of supply contamination from very shallow layers during intense rainfall events	To improve reliability, ensure boreholes are sited in most productive part of aquifer. Also important to improve maintenance of the hand-pumps – particularly within the dry season. Ensure shallow layers of groundwater source are cased out to prevent contamination
Large piped schemes from large dams and rivers	Capital intensive schemes for large towns and cities	Increased demand in cities. Changes in runoff and sedimentation affect storage	Larger storage should be able to cope with climate fluctuations Large increase in demand may lead to failure	Larger storage therefore more resilient, but increasing demand and reliability issues are a concern. Consider conjunctive use, supply backup and designing for higher demand at outset

Source: Bonsor et al. 2010

2.6 Key messages

Impacts on water availability

- There is still considerable uncertainty as to how water resources will be affected by climate change, particularly in data poor areas such as Africa. Uncertainty further increases within derived modelling of groundwater recharge and source behaviour. The impact of climate change on surface and ground waters will depend critically on how increased intensities of rainfall, and higher evaporative demands, affect soil moisture and the volume, variability and seasonality of runoff.
- Surface water sources and unimproved wells in shallow groundwater systems with limited storage are likely to be most vulnerable to extended dry periods and an increased intensity of rainfall events. Groundwater sources are, broadly speaking, less vulnerable to changes in rainfall. However, a much sharper appreciation of aquifer responses to changing climate and demand pressures is needed for informed groundwater development and management in changing climate.
- Groundwater sources drawing on water below 20m, from aquifers of moderate storage capacity, are likely to be much more resilient to climate change. It is uncertain how groundwater recharge patterns will be affected by climate change, but it is important to emphasise that only limited recharge (<10mm rainfall) is required to sustain groundwater-based domestic water supplies in most areas. That said, a significant minority of people in Africa – perhaps 100 million - depend on groundwater sources of limited storage which are highly vulnerable to any climate changes that reduce recharge.

Impacts on water quality

- There are clear links between access to safe, reliable water sources and human health, and existing problems could be exacerbated by greater climate variability. Increased flooding of latrines and unimproved sources could lead to a significant rise in diarrhoeal disease and infant mortality, and warmer water temperatures could lead to greater transmission of disease. Reduced functioning of water supplies during extended droughts could also increase the burden of disease.
- Both inland shallow groundwater and deeper coastal groundwater are at risk of increased salinity, due to increased evaporation and saline intrusion in coastal areas.

Technology choices

- Climate change does not change the basic nature of threats to water supply and sanitation technologies, but will change the severity and frequency of those threats.
- Because more water is likely to be ‘lost’ as runoff during floods, and dry periods are likely to increase, there will be a greater need to store water. Rainwater harvesting schemes may become less effective, as they are vulnerable to extended dry periods under existing climatic regimes. Overall, more reliance may need to be placed on water supply technologies which utilise a water store (e.g. groundwater or dams).
- Under a ‘no regrets’ approach, future technology choices should focus on more reliable sources, such as boreholes and deeper wells in more productive aquifers, and larger springs. If more vulnerable sources are to be used, greater site investigation and building in greater redundancy is required to ensure sources are sustainable within dry periods of high demand, or more vulnerable sources should be developed in combination with more resilient technologies to spread risk and provide water for different uses. All sources must be properly sited and constructed to protect water quality and ensure reliability, particularly in dry years.

Climate change in context

- Separating the impacts of and responses to climate change not easy, but it is clear that climate change is one of a number of pressures on water and livelihoods. In many countries there are multiple, inter-related pressures, including demographic shifts, urbanisation, changing patterns and levels of consumption, and pollution - drivers of change that will affect the supply of water, the demand for water, or both. In this respect, there is a danger that donor perspectives lose sight of developing country realities, and obscure a more balanced appreciation of existing risks and multiple pressures on water resources.
- At the same time, it is clear that national figures on water availability tell us little about disparities in distribution, access and control – factors that affect the scarcity experienced by local users and sectors, particularly the poor. In short, water scarcity is not environmentally determined. Here again, there is a danger that projections of scarcity based on national figures of water availability per capita, and the management solutions that follow, ignore or intensify problems of access and exclusion. The water ‘crisis’ is primarily one of governance and access, not absolute shortage. For this reason, *extending* access to affordable, reliable supplies remains key to meeting the MDGs and to building climate resilience.

3 Adaptation planning: policy responses and approaches

3.1 Introduction

Adaptation to the impacts of current and future climate change is unavoidable, whether planned or unplanned. Past emissions are estimated to involve unavoidable warming, even if atmospheric GHG concentrations remain at 2000 levels, with effects transmitted through hydrological and hydrogeological systems, and onto the ecosystems and people that depend on them. Adaptation is as an essential component of any climate change policy (Pielke et al. 2007). Arguments focus on which countries need to adapt, which sectors/areas/groups are most vulnerable, how best to provide support, and the level and type of finance required (Brown and Kaur 2009).

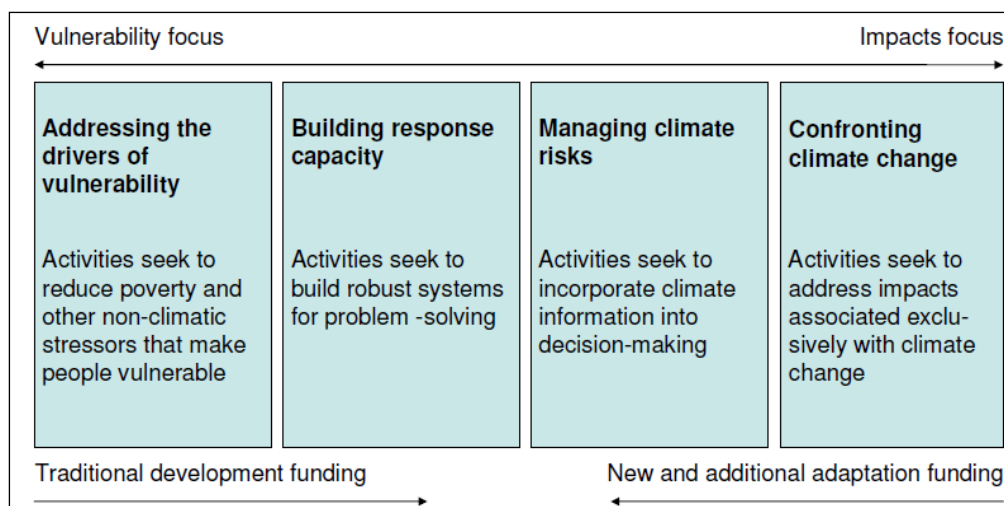
Definitions of adaptation in climate change literature are numerous (Schipper, 2007). In this report we use the definition of the UNFCCC Contact Group on Enhanced Action of Adaptation (October 2009) which views adaptation as:

Action to reduce the vulnerability and build the resilience of ecological and social systems and economic sectors to present and future adverse effects of climate change in order to minimise the threats to life, human health, livelihoods, food security, assets, amenities, ecosystems and sustainable development.

The relationship between adaptation and ‘normal’ development is a subject of much debate. Adaptation interventions often mirror ongoing efforts to promote sustainable development, making it hard to draw neat distinctions or, in terms of financing, to identify their incremental and/or additional cost over and above ‘development as usual’.

In this context, adaptation interventions can best be viewed on a continuum (Figure 3.1) – from activities that are needed both for adaptation and development, and which overlap almost completely with traditional development practice, to explicit adaptation measures targeted at distinct climate impacts, where the incremental cost is more clearly identifiable and quantifiable (Bapna and McGray 2008; Brown and Kaur 2009).

Figure 3.1: The adaptation continuum



An example of the former would be efforts to increase the numbers of people with access to improved water supply and sanitation, reducing dependence on unprotected and more vulnerable sources. An example of the latter would include the building of sea walls to protect against rising sea levels, higher dams, or higher capacity storm drains to cope with flash floods. The discussion above focuses on planned adaptation - deliberate policy decisions on the part of public agencies to address the impacts

of climate change. Planned adaptation interventions in the water sector include both supply and demand side measures that can be implemented using institutional, technical or market-based instruments. Supply-side measures involve increasing storage capacity or abstraction from water courses. Demand side options focus on saving water, and/or reallocating water between users and uses to increase ‘value’ or ‘output’ per drop, or to distribute water more equitably between users (Table 3.1). Supply-side options are favoured in national adaptation planning (see below).

Planned adaptation juxtaposes with *autonomous* adaptation, entailing any actions occurring naturally by private actors that take place without the direct intervention of a public agency (Aguilar 2001). While planned adaptation receives most attention from a public investment angle, the vast majority of adaptive behaviour is conducted autonomously by users themselves (Moench and Dixit, 2007). For example, the users of a village well or borehole may agree to restrict water use in the dry season to preserve supplies, or deepen a well to prevent it drying-out.

Table 3.1: Supply and demand-side adaptation interventions in the water sector

Type of intervention	Intervention	Addresses demand (D) or supply (S)	
		D	S
<i>Institutional/policy</i>	Promotion of indigenous practices for sustainable water use	*	*
	Inter-sectoral water transfer	*	
	Volumetric water rights	*	
<i>Technical</i>	Increased storage capacity – small to large		*
	Water-efficient irrigation e.g. drip systems	*	
	Desalination of sea water		*
<i>Market</i>	Expanded use of water markets to reallocate water to highly valued uses	*	
	Expanded use of economic incentives (metering & pricing) to encourage water conservation	*	

This section focuses on planned adaptation – the design and implementation of deliberate policy choices in response to current and future climate change. Currently such choices are being made at an international and a national level and a number of approaches have been developed to facilitate adaptation decision-making and implementation.

This section is separated into three main parts. The first part discusses climate change policy responses at the international and national level. The second provides an overview of current and emerging approaches to adaptation. The final part provides a summary of the key messages, and identifies potential entry points for influencing policy and practice.

3.2 Climate change policy making at the international and national level

Climate change policy making at the international level: the UNFCCC

To date, international policy responses aimed at addressing climate change have been largely driven by the United Nations Framework Convention on Climate Change (UNFCCC). The UNFCCC makes a distinction between *mitigation policies*, aimed at reducing GHG emissions, and *adaptation policies*, aimed at reducing the vulnerability of ecological and socio-economic systems to climate change impacts.

Under the Convention, adaptation is referred to under a number of Articles and Decisions. Whilst enshrined in Articles 4.1, 4.4, 4.8 and 4.9 of the Convention, not until the Marrakesh Accords (2001) was adaptation brought to the forefront of the negotiation process.

Adaptation issues are considered by the Conference of Parties (CoP) and its subsidiary bodies (subsidiary body on implementation (SBI) and subsidiary body on scientific and technological advice

(SBSTA). The Nairobi Work Programme on Impacts, Vulnerability and Adaptation to Climate Change (NWP) and the 'Buenos Aires programme of work on adaptation and response measures' are being implemented by these bodies. The NWP, which is a 5 year programme, facilitates exchange of information and practical experience amongst Parties on issues relating to the scientific, technical and socio-economic aspects of climate change impacts, and on issues concerning vulnerability and adaptation. The Buenos Aires programme aims at supporting the implementation of concrete adaptation programmes.

Adaptation is also one of the pillars of the Bali Action Plan (BAP), which charts out the course for negotiating a post-2012 climate change regime. As part of the BAP, Parties are currently negotiating a *Framework for Action on Adaptation*. Elements of this framework include:

- Identification of an enabling environment that will facilitate the implementation of national adaptation plans. This includes identifying ways to scale up financial and technological support for adaptation and the means to carry out vulnerability assessments;
- Identification of tools for risk reduction and risk sharing, such as insurance schemes; and
- Identification of avenues for economic diversification to spread risk and build resilience.

Box 3.1 provides an overview of the adaptation negotiations under the UNFCCC, and outcomes from the December 2009 COP15.

Climate change policy making at the international level: adaptation finance

The UNFCCC recognised the need for developed countries to provide financial support to developing countries to tackle climate change. However, the response to this has been patchy and has resulted in a web of differing funds.

Firstly, the Global Environment Facility (GEF) was assigned to deliver this support and set up two special funds under the Convention: the Least Developed Countries Fund (LDCF) and the Special Climate Change Fund (SCCF). The LDCF is was established to support Least Developed Country Parties (LDCs) to prepare and implement National Adaptation Programmes of Action. The SCCF was to fund projects. Both are funded by public finance from developed countries.

Alongside this, the Adaptation Fund was set up under the Kyoto Protocol, funded by share of proceeds from the Clean Development Mechanism (CDM). The Adaptation Fund was established to finance concrete adaptation projects and programmes in developing countries that are particularly vulnerable to climate change. It is supervised and managed by the Adaptation Fund Board, the World Bank act as trustees and the GEF provide secretarial support.

Outside the UNFCCC process, and in order to bridge the gap between the current and future international climate change agreement, some countries have established Climate Investment Funds (CIFs). The World Bank is the Trustee of the CIFs, which include a 'sunset clause' to ensure that the Fund's activities do not prejudice the outcome of UNFCCC negotiations.

The CIFs are intended to provide financing to pilot new approaches with potential for scaling up and are divided into two: the Clean Technology Fund (CTF) and the Strategic Climate Fund (SCF). The SCF is further divided into: the Forestry Investment Programme (FIP); the Pilot Programme for Climate Resilience (PPCR); and the Scaling-up Renewable Energy Programme (SREP).

At COP15, the Copenhagen Accord established: a High Level Panel to identify alternative sources of finance; and a Copenhagen Green Climate Fund to replace the GEF as the operating entity of the financial mechanism. The nature and structure of this Green Climate Fund is likely to be the focus of ongoing negotiations at COP16 and beyond.

Box 3.1: The adaptation negotiations under the UNFCCC

The negotiation process

Adaptation negotiations are taking place under the UNFCCC. Specifically adaptation is discussed under the Ad Hoc Working Group on Long Term Cooperative Action (AWG-LCA), the Subsidiary Body for Implementation (SBI) and the Subsidiary Body for Scientific & Technological Advice (SBSTA).

- *SBI* – in relation to adaptation, the SBI is reviewing progress under Article 4 of the Convention with a specific focus on paragraphs 8 & 9 and Decision 1/CP. 10. These include issues related to assessing the adverse effects of CC on developing countries; assessing the impact of the implementation of response measures and assessing how best to support concrete adaptation measures. Also relevant to adaptation, the SBI focuses on the financial mechanism for the UNFCCC, including the Least Developed Countries Fund and the GEF review.
- *SBSTA* – the SBSTA is reviewing the Nairobi Work Programme on Impacts, Vulnerability and Adaptation to Climate Change (NWP). The NWP is a 5 year programme, which is going into its second phase (focusing on implementation). The SBSTA is discussing in particular: what aspects and learning from the first phase should be taken up by the SBI and what the role of the NWP should be in the future (i.e. how should the NWP inform Parties on adaptation related issues?).
- *AWG-LCA* – the AWG-LCA is a subsidiary body under the Convention which has been tasked with presenting an outcome (by 2009) on ‘long-term cooperative action’ that will enable the full, effective and sustained implementation of the Convention beyond 2012. Under the AWG-LCA there are 3 contact groups that focus on: 1. Developing a Shared Vision on Adaptation; 2. Means to Implement Adaptation; and, 3. Enhancing Financial and Technical Support for Adaptation.

What is being negotiated?

- Currently Parties are negotiating the development of a Framework for Adaptation. Components of this framework include: (a) the creation of an enabling environment; (b) risk reduction; and (c) economic diversification.
- Current negotiations are at a stand-still due to a deadlock on aspects related to the creation of an enabling environment. Parties are yet to agree on how best to define adaptation, to carry out vulnerability assessments and to scale up support for adaptation, specifically financial support. While there is some agreement that the definition of adaptation will vary across countries and scales and that vulnerability assessment will include criteria like risk exposure and coping capacity, there is little agreement on defining the scale of support required for adaptation and the means to mobilise and deliver this support.

Where is water in the negotiations?

- Water has been identified as one of the most vulnerable sectors to climate change, and the IPCC has produced a technical paper on water and climate change (the first sector to receive solo attention). Water-related projects dominate the priority projects identified under the NAPA process. The Global Environment Facility (GEF) Trust Fund also identifies water as a key ecosystem requiring adaptation support.
- The negotiations themselves have not gone into details related to adaptation in different sectors. However, at the last two Conference of Parties (in Poznan 2008 and in Bonn 2009), two side events organised by NGOs focused on water and climate change.
- Arising out of the COP15 Copenhagen proceedings, the Copenhagen Accord provides a “politically binding” declaration producing commitments that aim to be clarified and defined by the international community in future COPs. The accord places particular emphasis on the provision of both short term and longer term¹ financial support to developing nations for the purposes of mitigation, adaptation and forest conservation. Despite tremendous effort and pressure from various stakeholders to include water in the Copenhagen negotiations, the Copenhagen Accord makes no specific mention of water issues. However, given the intrinsic relationship between adaptation and water, many of the proponents of the accord, dealing particularly with adaptation, are of relevance to the water sector.

Engaging with the negotiations

- There are a number of ways to engage with the negotiations. Formal engagement includes the submission of statements to the Secretariat, which are then considered by the Parties and organising Ministerial events to ensure that a particular topic is brought onto the negotiation agenda. Informal engagement includes discussions with delegates, which can then be reflected during the negotiations.
- In terms of areas of engagement, experiences from the water sector can feed into a number of existing adaptation streams. For instance, under the theme related to ‘developing a shared vision on adaptation’, the water sector could highlight the role of water in facilitating adaptation and provide clarification on whether water should be seen as a sector on its own or as a cross-cutting resource. Under Means of Implementation, the water sector has a lot of experience related to vulnerability and adaptation assessments (see Water Economy for Livelihoods assessment – ‘WELS’ - below) and could inform debates on economic diversification.

Climate change policy making at the national level: the NAPA and NatComm process

At a national level, government-led responses to the UNFCCC in developing countries have revolved around the development of National Communications (NatComms) and, in least developed countries (LDCs), around National Adaptation Programmes of Action (NAPAs). Both Annex I and Non-Annex I countries are required to prepare NatComms under the UNFCCC. Non Annex I countries provide information on national circumstances, vulnerability assessment, financial resources and transfer of technology, and education, training and public awareness needs in relation to climate change.

The purpose of a NAPA is to identify priority activities that respond to a country's urgent and immediate needs with regard to climate change adaptation. To achieve this, the NAPA process requires LDCs to (a) synthesise available information on the adverse effects of climate change, (b) based on such information, assess vulnerability to *current* climate variability and extreme weather events, and (c) assess whether climate change is causing increases in associated risks. The Plan of Action should, according to the UNFCCC guidelines on NAPA preparation, be conducted in a participatory manner, adopt a multidisciplinary approach, and incorporate a sustainable development perspective (Bjorkland, 2009). NAPAs should also be action-oriented and country-driven, flexible, and based on national circumstances (UNFCCC 1).

Prominence is given to community-level input as an important source of information, and to the identification and strengthening of existing coping strategies. However, whilst the NAPA process has provided a useful entry point for identifying adaptation needs, current debates and the negotiation process under the UNFCCC recognise that planning needs to account for longer term climate beyond 'current' variability and extremes.

In order to finance NAPA projects, the Least Developed Countries Fund (LCDF) was set up under the UNFCCC to support a working programme to assist LDCs in NAPA implementation. While most LDCs have completed and formally presented their NAPAs to the UNFCCC¹, implementation of priority projects has been slow to commence. Having completed its NAPA in 2001, Bhutan became the first country to commence implementation of its programme on the prevention of Glacial Lake Outburst Floods (GLOFs) in 2008. Since then, NAPA project implementation and financing amongst a number of LDCs has gradually increased.

Addressing water concerns in the NAPA process

Table 3.2 highlights a number of water-related adaptation priorities and projects identified by developing countries and LDCs in their adaptation strategies and NAPAs. Most NAPAs identify the water 'sector' as vulnerable to climate change, and include water-based interventions. However, these are typically project-based and not mainstreamed into wider development policy. Most focus on supply-side infrastructure rather than resource management.

A number of these projects address increasing variability of rainfall, water scarcity, floods and droughts, water salinity and water pollution. In order to manage climate induced impacts on water availability, both supply and demand side interventions are being proposed, though with much greater emphasis on supply-side infrastructure. For instance, the Ugandan and Ethiopian NAPAs focus on the construction of low-cost, accessible, irrigation schemes, whilst the Indian Plan focuses on investing in energy efficient technology for desalinisation and waste-water reuse to supply water to coastal and urban areas. On the demand side, India proposes to regulate power tariffs and reform pricing.

¹ As of September 2009, 43 out of 48 NAPAs had been completed. Upon completion NAPAs are presented to the UNFCCC and made available for public dissemination through the UNFCCC website.

Table 3.2: National Adaptation Plans and Projects: some examples

Country	Project/Adaptation Strategy	Activities	Climate risk/vulnerability identified
<i>Bangladesh</i>	Providing drinking water to coastal communities to combat enhanced salinity	Identifying and developing alternative sources of safe drinking water; Improved management system for safe drinking water supply (IWRM)	Addressing increased salinity due to sea level rise.
<i>Ethiopia</i>	Develop small scale irrigation and water harvesting schemes in arid, semi-arid, and dry sub-humid areas	Identification and development of sites for water harvesting, small-scale irrigation dams and boreholes.	To reduce risk to increased rainfall variability.
<i>India</i>	India's 11 th Five Year Plan & The National Action Plan on Climate Change (NAPCC) focuses on adaptation to Climate Change. The Water sector features prominently in both. The National Water Mission is one of the eight missions that have been established under the (NAPCC).	A National Water Mission has been established under the NAPCC. It will ensure IWRM that will facilitate water conservation, minimise wastage and ensure more equitable distribution both across and within states. A number of interventions will form the basis of adaptation in the water sector. Proposed interventions include: Infrastructure that enables water managers to store and transfer water; Enhancing groundwater recharge; Development of desalinisation technology and recycling of water. Demand side interventions also proposed: Regulation of power tariffs for irrigation to manage ground water; Increasing water use efficiency through regulatory mechanisms, differential entitlements and pricing; Adoption of irrigation systems that rely on sprinklers, drip and furrow irrigation; Incentive structures to promote water-neutral or water positive technologies.	The main climate induced threats in the water resources sector include: A decline in total run-off for almost all river basins; Increased salt intrusion in coastal freshwater resources.
<i>Mozambique</i>	Management of Water resources under the framework of climate change	Improve control and evaluation of river waters to reduce the impact of flood and drought; Improving management of shared waters with neighbours; Control river pollution.	Need to address the impact of CC on existing adverse effects of floods, droughts and river pollution.
<i>Tanzania</i>	Improving Water availability to drought-stricken Communities in Central part of country	To provide water in drought stricken areas. To ensure sustainable-use.	Need to address water scarcity.
<i>Uganda</i>	Community Water and Sanitation Project	To increase and scale up water supply and sanitation among vulnerable communities in disaster prone areas (e.g. Increase latrine coverage); strengthen community awareness on climate change induced health impacts; Strengthen emergency and disaster preparedness & response programmes.	Increase in intensity and frequency of extreme weather events, which in turn leads to health and sanitation impacts.
<i>Uganda</i>	Water for Production Project	Providing better access to and better use of water for crop and animal production (rain water harvesting; low cost irrigation; construction of dams; community involvement and M&E).	Increased climate variability, which will impact water availability

NAPAs: a critique

NAPAs are designed to take an inclusionary approach and address a wide variety of equity and justice issues during the course of their development. Platforms for input by the poor, socially excluded, and those deemed most vulnerable to the effects of climate change are meant to be provided throughout the entire process. In practice however, government-level deliberation can leave little space for purposeful, inclusionary dialogue with outside stakeholders. In addition, the notion of “adaptation as a right”, based on equitable sharing of the burdens induced by climatic change, and acknowledgment of an “adaptation deficit” in developing countries, have not been prominent in the majority of NAPA proposals, particularly within the African context (Osman-Elasha and Downing, 2007).

In their evaluation of all LDC NAPAs currently completed in relation to the water sector², Bjorkland et al (2009) observe a lack of alignment between the content of the NAPAs and that of PRSPs, NDPs, IWRM plans, MEA Action programmes, and other national development plans relevant to the water sector. However, this ‘mainstreaming’ approach would imply a long term perspective, while the instructions in the NAPA Guidelines to be ‘action orientated’ and ‘to set clear priorities for urgent and immediate adaptation activities’ imply a much shorter term perspective. The PPCR (see above) aims to demonstrate how adaptation planning can be better integrated into existing planning in order to take a longer term view.

In addition, a failure to recognise and address existing barriers - institutional, political etc – to planning and implementation; a focus on addressing water issues through a supply rather than a river basin (resource) perspective; as well as a lack of specificity with regards to climate change impacts, adaptation measures and quantification of associated costs, have generally plagued all NAPAs prepared thus far. Their assessment also highlights a failure to address regional, transboundary issues when several countries share a river basin.

Looking ahead

Whilst many have been quick to openly criticise the NAPA process, highlighting its lack of flexibility, delays in implementation, and general focus on large-scale projects, the fact remains that NAPAs constitute the sole effective assessment of the nation-wide adaptation needs of individual LDC nations. The participatory nature of the NAPA process in some countries has also provided a platform for effective interaction between government, academia, NGO, and other stakeholders. Indeed, perhaps the greatest ‘success’ of the NAPA process has been to communicate the issues, pitfalls and opportunities associated with climate change to a much wider audience.

A review of completed NAPAs at COP14 in Poznan contended that National Adaptation Plans should go beyond the initial groundwork covered under current NAPAs, aiming to: create living documents to reflect new and more detailed information and to reflect changes in domestic priorities; establish a formal process, integrated into all relevant decision-making processes; and build on the lessons learned from existing processes like the NAPA. Indeed a number recently completed³, and soon to be completed NAPAs, have built on these guidelines to produce a more holistic assessment of development and management needs for the water sector (Bjorkland et al, 2009).

3.3 Adaptation responses

A number of approaches have been developed to guide adaptation planning. These are designed to help define and identify adaptation interventions, and to help identify means to implement such interventions. However, while often described as ‘new’, all focus on understanding existing vulnerability and how people cope with seasonality and shocks.

Amongst others, vulnerability assessment approaches, scenario-based planning and adaptive management approaches all provide frameworks to facilitate adaptation planning in response to the uncertainty surrounding the impacts of climate change.

² As of December 2008.

³ Bjorkland et al (2009) provide observations from the evaluation of recently submitted NAPAs by Mozambique and Sierra Leone.

Mainstreaming as an approach is being used to provide a framework to implement adaptation. In addition, approaches such as community-based adaptation (CBA) and ecosystem-based adaptation (EBA) provide frameworks intended to facilitate both adaptation planning and implementation.

These approaches are now discussed. Section 4 then provides examples of how these approaches have been piloted and operationalised, principally by the donor community.

Vulnerability and adaptation frameworks

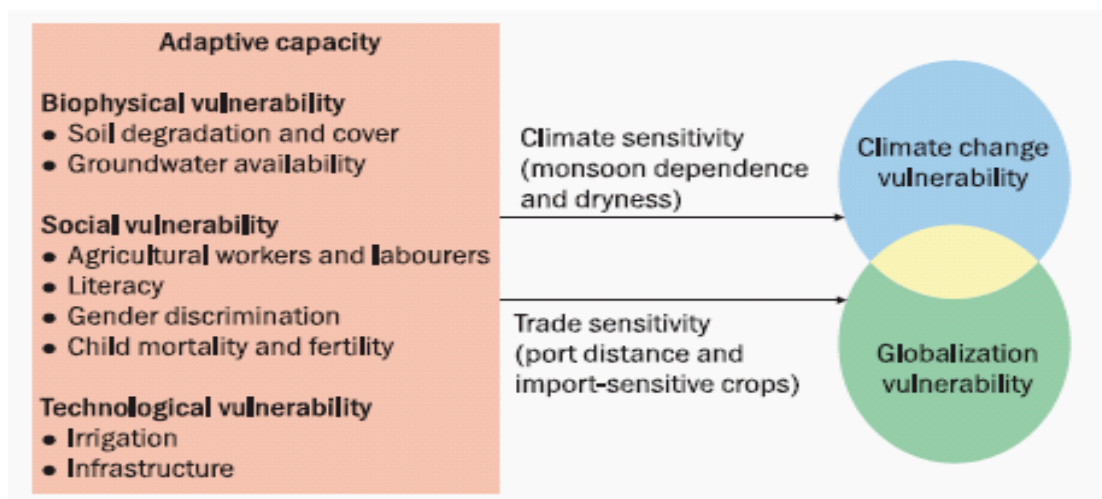
Vulnerability assessments (VA) play a key role in adaptation planning. Given that vulnerability is a function of exposure and sensitivity of a system to climate change, and its adaptive capacity, VAs aim at assessing:

- How exposed the concerned system is to climate change; ;
- How sensitive it is to this exposure; and,
- To what extent the system can adapt to climate induced impacts.

A number of frameworks have been designed to carry out vulnerability and adaptation assessments. Broadly these can be divided into impact and adaptation frameworks. ‘Impact’ frameworks are sometimes referred to as “first generation” or “top down” frameworks. They were mainly designed to help understand the potential long-term impacts of climate change. The ‘adaptation’ frameworks, sometimes referred to as “second generation” or “bottom up” frameworks, have been designed to focus on adaptation and involve stakeholders.’ (UNFCCC 2). The UNEP Handbook⁴ provides details on conducting an impact assessment whereas the UNDP Adaptation Policy Framework⁵ (APF) provides details on conducting an adaptation assessment.

Local level VA can also be carried out using asset-based approaches and through a Water Economy for Livelihoods (WELS) analysis - see section 4. Vulnerability assessments can also take into account other drivers of socio-economic vulnerability. For instance, in India, the concept of double exposure (exposure to climate change impacts *and* exposure to globalisation) was used to identify vulnerability hotspots in the country (Figure 3.2).

Figure 3.2: Determinants of vulnerability: assessment of vulnerability of Indian agriculture to 'double exposure'



Source: TERI (2008).

Scenario-based planning & adaptive management

Specific to the water sector, the IPCC Technical Paper on Water (Bates et al. 2008) outlines scenario-based planning and adaptive management as approaches that can be used to address adaptation planning in the light of climatic uncertainty:

⁴ The UNEP Handbook is available at: http://www.falw.vu.nl/images_upload/151E6515-C473-459C-85C59441AoF3FB49.pdf

⁵ Information on the APF is available at: <http://www.undp.org/cc/whatsnew.htm>

- Scenario-based approaches to planning – based on the development of plausible, future storylines to facilitate decision making in the context of uncertainty. Scenario development is based on a set of assumptions of the key relationships and driving forces of change. These include predictable and unpredictable features of climate change, the environment and socio-economic factors. Existing scenarios include those developed by the IPCC and the MA (as described in Section 1). Scenario-based planning is being practiced in the UK and Australia.
- Adaptive management – involving greater use of water management measures that are ‘robust to uncertainty’. For example, storm drains that can cope with higher (future) discharges, and groundwater boreholes rather than shallow wells in vulnerable hydrogeological environments. Monitoring and evaluation (M&E) will play a key role in adaptive management, and is described in more detail in section 4.

Mainstreaming and Integrated Water Resource Management

Mainstreaming implies that awareness of climate impacts and associated measures to address these impacts are integrated into existing and future development policies and plans of developing countries, as well as multilateral institutions, donor agencies and NGOs. Country experience suggests that successful mainstreaming requires institutional and policy coordination and prioritisation of adaptation options in the budget planning process (see section 4).

Integrated water resource management (IWRM) could play an important role in facilitating effective mainstreaming (Nicol & Kaur, 2009). The IWRM approach has many elements, including: multi-stakeholder dialogue and decision making; the coordination of land and water resources management; recognition of water quantity and quality linkages; planning for conjunctive use of surface and groundwater; and protecting and restoring natural systems. IWRM aims to ensure inclusive decision-making and provide a platform for effective conflict resolution between competing water uses and users in different parts of a basin. Addressing climate change issues in IWRM implies explicit consideration of climate-hydrological uncertainty, and flexibility, in management decisions.

Community Based Adaptation and Ecosystem Based Adaptation

Community Based Adaptation

Community Based Adaptation (CBA) is a bottom-up and ‘place-based’ approach to adaptation. CBA begins by identifying areas and communities that are most vulnerable to climate risk, and then uses the best available science on climate induced impacts to engage with vulnerable groups (Huq & Reid, 2007). CBA, including community risk assessment, is participatory in its approach to assessing hazards, vulnerabilities and capacities that can support adaptation planning (Aalst, et al, 2007).

At present, the NAPA process (see above) is predicated on identifying local vulnerability and building on local coping capacities. However, the projects identified do not, as yet, deal explicitly with access and equity issues. Community access to adaptation financing is also lacking and is currently being discussed only under the Adaptation Fund that will be operational under the Kyoto Protocol. Existing structures, such as the Least Developed Countries Fund that finances the implementation of NAPA projects, only allow UN agencies and the World Bank to access funds and implement projects. The effectiveness of such an approach in terms of participatory, community led planning and access to benefits is questionable (Kaur (forthcoming)).

Ecosystem Based Adaptation

Ecosystem Based Adaptation (EBA) is based on the premise that well managed ecosystems support adaptation by increasing the resilience of livelihoods to the impacts of climate change. EBA includes a range of local and landscape scale strategies. It is compatible with a number of other adaptation approaches, like CBA, disaster risk reduction and IWRM. For instance, given that many of the impacts of climate change will be felt through water, better management of water resources is central to adaptation. The IUCN (2009) argue that EBA that builds and maintains natural infrastructure in river basins will strengthen water, food and energy security in the face of climate change.

3.4 Key messages

Adaptation needs and definitions

- Adaptation to the impacts of current and future climate change is unavoidable, whether planned or unplanned. Adaptation is now viewed as an essential component of any climate change policy; arguments focus on which countries need to adapt, which sectors/areas/groups are most vulnerable, how best to provide support, and the level and type of finance required.
- Definitions of adaptation in climate change literature are numerous. Essentially, adaptation is about increasing the resilience and capacity to cope with the physical impacts of climate change. Adaptation measures aimed at enhancing the coping capacity of systems often fall into the remit of scaled up development interventions. In contrast, measures aimed at reducing exposure to the impacts of climate change require investments that are over and above a 'development as usual' scenario.

Adaptation planning

- At a global level, adaptation decision-making is carried out under the UNFCCC. At a national level, government-led NCs, NAPAs and Adaptation Strategies provide entry points into the adaptation decision-making process. Current adaptation planning at the global level focuses on: (a) developing a shared vision on adaptation; (b) identifying means to implement adaptation; and (c) enhancing financial and technical support for adaptation.
- Current adaptation planning at a national level focuses on: (a) assessing vulnerability to climate change; (b) identifying adaptation strategies; and (c) identifying means to implement adaptation strategies, including the scaling up of technical and financial support, and designing institutional responses that are effective in coordinating and mainstreaming adaptation responses.
- Most NAPAs include water-based interventions. However, interventions are typically project based and not mainstreamed into wider development policy, for example PRSPs. Moreover most focus on supply-side infrastructure rather than resource management.
- NAPAs do not typically pay much attention to sanitation. The link between sanitation and climate change is a gap that warrants further exploration.
- A number of approaches have been used to facilitate adaptation planning and implementation. Amongst others, vulnerability assessment, scenario based planning and adaptive management all provide frameworks to support decision making in response to climatic uncertainty. Approaches like CBA and EBA provide frameworks that facilitate both adaptation planning and implementation, though their 'value added' over existing approaches to pro-poor development planning is questionable.
- The effectiveness of existing adaptation interventions and approaches is yet to be determined. Issues related to equitable access, mal-adaptation and the resilience of interventions *vis-à-vis* long term climate change need to be taken into account in the development of the next generation of adaptation strategies.

Engaging with adaptation planning

- At a global level, organisations can engage with the negotiations through formal or informal means and help flesh out the issues that are being negotiated. Field-based experience can inform debates on identifying options and approaches. For instance, guidance on technology choices that provide resilience to climate change is required. Experience can also inform debates on economic diversification as an adaptation strategy.
- At a national level, organisations can engage with the NAPA process as NAPA development is a 'live' process. Inputs into hazard, vulnerability and adaptation assessments could help fill important knowledge gaps.
- At a community level, organisations can play an effective role in disseminating climate related knowledge that will inform household and community level decision-making. Organisations can

also do much more to climate-proof their own interventions, for example by ensuring that Water Safety Plans (WSPs – see Section 4) include an assessment of climate related risk and mitigation strategies.

4 Pro-poor adaptation in WRM and WASH: operational responses

4.1 Introduction

This section discusses how some of the policy responses and approaches to adaptation planning outlined in Section 3 have been put into practice. Specifically, the section discusses how pro-poor adaptation could be integrated into programme and project planning in the water sector.

Climate adaptation is a relatively new, complex and cross-cutting issue and its precise *operational* implications are not well-defined (Aalst & Mitchell, 2008). As such, integrating climate risk management into the water ‘sector’ is in its very early stages. Nonetheless, there are a range of actors involved in the piloting of initiatives, programmes, projects and toolkits designed to operationalise ‘adaptation’ in practical and measurable ways (see World Bank, 2006).

This section reviews these adaptation measures, providing an overview of the major toolkits, case-studies, good practice and lessons learned to date. This will provide a better understanding of how climate risk management can be integrated into project planning. The section is split into five parts that discuss the following issues in turn: the actors involved in pro-poor adaptation; toolkits for climate screening and vulnerability assessment; examples of climate mainstreaming; community-level adaptation; and M&E.

4.2 The key actors in climate adaptation in the WASH sector

Various actors have been involved in implementing adaptation policy and in integrating pro-poor WASH adaptation into programmes and projects. These actors can be identified at the national, sub-national, local and intra-levels and they can fulfil important, but differing, pro-poor adaptation roles and functions (summarised in Table 4.1 below). However, the precise roles of these actors may differ somewhat depending on the specific context.

At the national level, there are the central Ministries, National Water Authorities and National Water User Associations (WUAs). Their main functions are, in principle, to integrate climate change into development policy and management, to provide a legal and regulatory framework conducive to adaptation, and to prioritise adaptation by ensuring budgetary allocation to relevant programmes and projects.

Also at the national level, some countries have set up ‘coordination’ or ‘expert’ committees comprised of high level civil servants, members of parliament, experts, donor officials and civil society representatives. For instance in India, the National Water Resources Council is responsible for conflict-resolution and is increasingly involved in adaptation planning. These committees play an important role in the coordination of cross-sector and multi-stakeholder adaptation initiatives and also provide technical advice and quality control.

At the sub-national level are actors with the main function of providing a link between national governments and local government, water users and communities. These actors include provincial/regional governments or dedicated departments, such as Departments of Sanitation, who are responsible for water management in their sectoral and geographical area of jurisdiction.

Operating at the local level are a range of actors whose main functions are defined as delivering water services to front-line resource users, ensuring the representation of local water needs in national processes and implementing community-based water management and adaptation.

At an ‘intra-level’, that is below and across the national level, the major actors include the private sector, civil society groups, NGOs and donor institutions. These types of actors fulfil a range of different functions, depending on the specific case, country and context.

It should be noted that, to date, many of these roles and functions are only being partially fulfilled or are not fulfilled at all (Aalst & Mitchell, 2008). Nonetheless, certain actors across SSA and South Asia have promoted initiatives designed to integrate climate risk management into programme and project planning. These initiatives are now discussed.

Table 4.1: The key actors involved in climate adaptation in the water sector

Level	Actors	Main 'Adaptation' Functions
National	Central ministries	<ul style="list-style-type: none"> Develop policy, planning and regulatory frameworks on adaptation issues. Allocate financing for national/sub-national initiatives.
	Management & planning boards	<ul style="list-style-type: none"> Provide technical inputs into planning processes. Oversee implementation of national policies.
	National water authorities/councils	<ul style="list-style-type: none"> Facilitate inter-sector and multi-level coordination, conflict-resolution and information exchange.
	Water commissions	<ul style="list-style-type: none"> Facilitate transboundary cooperation.
	National associations of water users	<ul style="list-style-type: none"> Enhance negotiating power of water user associations at the national level.
	Research organisations	<ul style="list-style-type: none"> Provide data to guide adaptation planning.
Sub-national	State/provincial offices	<ul style="list-style-type: none"> Secure cost recovery for activities in their jurisdiction.
	Catchment councils	<ul style="list-style-type: none"> Prepare plans for optimum water use in their area.
Local	Local government & village councils	<ul style="list-style-type: none"> Support and lead local/community-based adaptation.
	Water User Associations	<ul style="list-style-type: none"> Represent a set of users in adaptation initiatives.
	Community structures	<ul style="list-style-type: none"> Facilitate community-level adaptation projects.
Intra	Private sector	<ul style="list-style-type: none"> Invest in adaptation-related activities such as micro-finance, micro-insurance or carbon markets.
	NGOs	<ul style="list-style-type: none"> Range of initiatives. Play an important role in promoting community-level adaptation measures.
	Donor institutions	<ul style="list-style-type: none"> Provide financial and technical assistance.
	Media	<ul style="list-style-type: none"> Disseminate CC information thereby facilitating adaptive decision-making and mobilising support for CC.
	Training bodies	<ul style="list-style-type: none"> As highlighted in the Hyogo framework, knowledge and education helps build a culture of safety and resilience.

Source: Levina 2006

4.3 Toolkits for climate risk management, screening and vulnerability

The range of existing initiatives designed to promote adaptation are based broadly on the concept of Climate Risk Management (CRM). CRM is an approach to climate-sensitive decision making that is increasingly seen as the way forward in dealing with climate variability and change. In the simplest of terms, CRM seeks to promote sustainable development by reducing the vulnerability associated with climate risk. Further, CRM adopts the 'no regrets' principle described in Section 2. This involves taking climate-related action that makes sense in development terms anyway, *whether or not* a specific climate threat actually materialises in the future.

It should be noted that a range of different terms have been coined to describe a risk management approach. These terms include: 'climate proofing', 'climate mainstreaming', 'disaster resilience', 'disaster risk reduction', or, 'integrated risk reduction' (Aalst & Mitchell, 2008). This diverse terminology can usefully capture some technical differences across the board of CRM approaches. However, the different terms can sometimes lead to confusion, even among the initiated. The important thing to remember is that most terms essentially refer to the identification of potential impacts of climate variability and to the design of strategies to adapt to such impacts.

Climate risk screening

Climate risk screening is a process-based approach that could be applied to WASH sector investments. If used effectively, screening aims to: (a) raise the profile of adaptation to climate change in project planning; (b) ascertain the extent to which existing development projects already consider climate risks or address vulnerability to climate stress; and change; (c) reduce the risk of 'under-performance' of

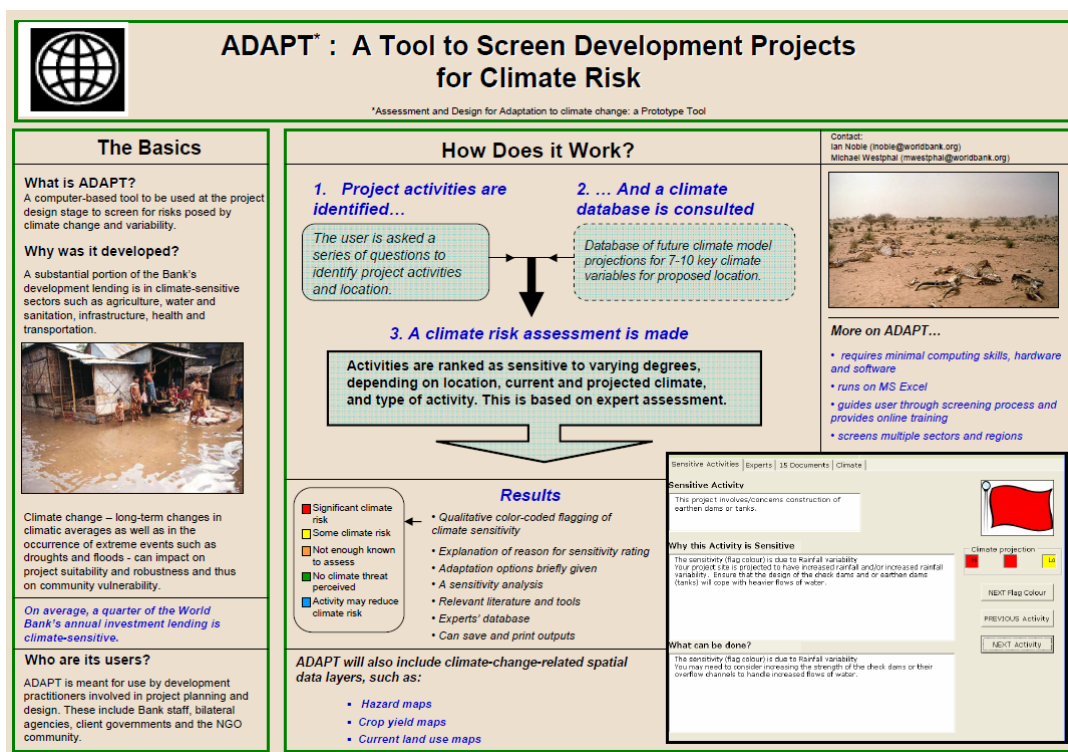
investments and guide project managers to options that can minimise risks and, (d) identify opportunities and strategies for incorporating climate change into future projects.

The ADAPT toolkit

The World Bank is one agency leading in the development of a screening toolkit. In terms of the WASH sector, the Bank takes the view that climate change will have a profound impact on the water cycle, water availability, water allocation, and demand, which will have a major impact on project suitability and robustness, and community vulnerability. The Bank argues that systematic screening can help deal with such challenges (World Bank, 2008).

In this context, the Bank is developing a toolkit called '*Assessment & Design for Adaptation to Climate Change – A Prototype Tool*' (ADAPT). The ADAPT methodology can be summarised as follows (see Figure 4.1).

Figure 4.1: An overview of the ADAPT methodology



Source: World Bank, 2009

First, the ADAPT user inputs project objectives, activities and location. Second, a climate database is consulted which takes into account a future climate model for 7-10 key climate variables relevant to the project. The third step is that a climate risk assessment is produced, which ranks the degree of climate sensitivity of the project activities. Finally, ADAPT generates a set of outputs that explain the sensitivity rankings and that provide 'adaptation options'. ADAPT is not yet publicly-available, but the Bank claims it will be an 'easy-to-use' computer-based toolkit for development practitioners. In view of the problems faced in downscaling GCMs to country or basin levels, however, it is unclear whether this will produce clear guidance.

The ORCHID toolkit

Another risk screening tool that could be applied to the WASH sector is called '*Opportunities & Risks from Climate Change and Disasters*' (ORCHID). As its name implies, ORCHID not only identifies risks, but also highlights opportunities. It is a process-based methodology that has been piloted by UK's Department for International Development (DfID) in Bangladesh (Tanner et al. 2007). Much like ADAPT, ORCHID aims at facilitating complex decision-making processes under uncertain information and data gaps. It places the emphasis on analysing and assessing planned development initiatives, on

assessing current and projected climate variability, on managing specific risks and identifying broader opportunities to reduce vulnerability and achieve pro-poor outcomes.

Some key lessons have been learned from DfID's ORCHID experiences. First, previous to using ORCHID, climate change adaptation issues had been picked up in very few of DfID's environmental procedures or project risk assessments. Second, ORCHID helped reinforce the contribution that many programmes already make to vulnerability reduction and the formalised screening approach focused this further. Third, the screening process helped prioritise ongoing and future DfID-funded programmes, and options for adaptation and disaster risk reduction were assessed for integration into the portfolio (Klein et al. 2007). There is not, as yet, evidence of how ORCHID can be applied effectively for the screen of WASH investments.

Financial screening tools

Another major type of 'screening' tool is composed of various financial instruments. These include: Cost Benefit Analysis, Cost Effectiveness Analysis and Multi-Criteria Analysis (Diop & Bosch, 2008). These are essentially designed to assist project managers to ensure the cost-effectiveness of adaptation, to prioritise areas for investment and to reflect on the financial sustainability of adaptation initiatives.

Another central benefit of such instruments is that they often serve to illustrate the sound financial case for pro-poor adaptation. In fact, a growing body of evidence suggests that the benefits generated by investment in adaptation and disaster preparedness in the WASH sector far outweigh the costs (see Christian Aid, 2005; Stern Review, 2005). Risk screening, however, is only one of a range of inter-related tools in the CRM field.

Vulnerability assessments

Vulnerability assessment (VA) is another tool for CRM. As described in section 3, VAs seek to measure the degree to which a social system is susceptible to, and able to cope with, the adverse effects of climate change. This type of analysis, which feeds into the screening process, can better inform adaptation planning. Some agencies have developed methodologies for VA, which have been applied to the WASH sector.

For instance, UNDP and the GEF argue that a 'good practice' VA should target a specific sector and/or group and should develop a comprehensive 'vulnerability baseline', against which project impacts can be measured. An operational VA should include the following:

- An analysis of existing knowledge of vulnerability and coping mechanisms;
- An identification of the manifestations of CV at the sector or local level;
- An assessment of the degree to which stakeholders have adapted to CV; and,
- An assessment of what stakeholders need in order to adapt (Crane et al. 2008).

Water Economy for Livelihoods Approach (WELS)

The WELS approach illustrates how a VA can be systematised and applied in the WASH sector. WELS has been piloted by ODI in the Oromiya region of Ethiopia under the RiPPLE programme (see Ludi, 2009). The approach can be used to quantify the impact of climate hazards on household water access, and its knock-on effects on food consumption, production and income. This information can be used to determine which wealth groups, in which areas, are likely to be hardest hit by a drought (for example), and which water-based interventions would work in supporting and protecting livelihoods (see Box 4.1).

Box 4.1: Vulnerability and the Water Economy for Livelihoods approach (WELS)

WELS builds on the analytical framework of the Household Economy Approach (HEA) developed in the early 1990s by Save the Children UK. WELS is a tool that can be used to:

- Evaluate water access by different wealth groups;
- Characterise the nature of vulnerability of each wealth group to water-related hazards;
- Assess the impact of changes in access to water on food and income sources; and,
- Identify triggers for appropriate and timely water interventions and development programmes.

Baseline data can be used for a variety of outcome analyses. In an ODI-led pilot study underway in Oromiya Region in Ethiopia, WELS and HEA data are being used to predict the likely impacts of climate change and the likely impacts of climate change adaptation measures on different households. The data will help identify the following:

- Impacts of likely climate change hazards on water availability, access, and use, as well as food and income for different wealth groups in different livelihood zones;
- Impacts of climate change adaptation interventions on water availability, access, and use;
- Policy options to support positive livelihood outcomes; and,
- Policy coordination needs and institutional mechanisms for adaptation implementation.

Water safety plans

One approach that can be adapted to include climate risk screening, or water point vulnerability to climate change, is water safety planning. Originally developed as a tool for assessing threats to water quality (WHO 2004), water safety plans (WSPs) can be extended to include water availability and reliability concerns, and scenario-based planning for climate change.

An ‘extended’ WSP would be designed to ensure the safety and reliability of adequate supplies of water through the use of a comprehensive risk management approach, ideally from catchment through to consumption and use, with significant end user participation in both the identification of risks and in their mitigation. St John Day (2009) identifies three key elements:

- Identification of credible risks to water supply systems;
- The prioritisation of those risks; and
- Establishment of controls to manage identified risks.

At a community level, credible risks and prioritisation areas related to threats posed by climate change (and other drivers of change) can be grouped as follows:

- Ensuring sufficient water quantity for domestic and productive uses in the light of (a) greater climate variability and expected changes in the area (e.g. more droughts and floods), if known; (b) likely changes in the demand for water.
- Ensuring appropriate and realistic water quality for domestic and productive uses in the context of (for example) the risk of contamination resulting from heavy rainfall events.
- Improving the equity of access to water sources, including provision for ‘fair’ rationing during periods of limited availability (e.g. droughts) and the maintenance of basic needs for all.
- Ensuring that protection and safety considerations have been factored into the selection, design and siting of water points, for example in terms of the risk of contamination from on-site sanitation under conditions of intense rainfall and flooding.
- Ensuring that longer-term water resource management needs are discussed with communities and factored into decisions around technology choice, siting, service levels and rules/agreements concerning water withdrawals during drought or periods of peak demand.

Some lessons learned from screening

As these screening tools are in their pilot stages, it remains to be seen how effective they are in promoting adaptation. Nonetheless, some key lessons have been learned from operational experience to date.

First, if screening processes are to be effective, there is a need to increase the scope and credibility of climate-related information. Currently, particularly across Africa, climate observation networks lack capacity to produce comprehensive and up-to-date data. One goal in the WASH sector, then, is to strengthen capacity to monitor *local* manifestations of *existing* climate variability on water resources (Hellmuth et al. 2007).

Second, a working paper from the Tyndall Centre argues that risk screening must be comprehensive in its remit (Klein et al., 2007). This makes it an extremely complex process, especially when dealing with large systems such as transboundary waters. The Tyndall Centre identifies three areas that must *all* be considered in the screening processes:

- *Risk assessment*: aimed at quantifying the extent to which potential impacts of climate change pose a risk to the cost-effectiveness and other aspects of the viability of a project.
- *Vulnerability assessment*: aimed at evaluating the vulnerability to climate change of the community or ecosystem at which a project is targeted.
- *Environmental impact assessment*: aimed at analysing the extent to which a project would affect an eco-system's vulnerability to climate change.

A third issue concerns the top-down, technical and expert-orientated nature of the screening approaches outlined above. A major challenge is to ensure that screening processes are bottom-up and that they effectively integrate the knowledge and needs of the poor and vulnerable (described further below).

4.4 Cases of climate mainstreaming

Another way in which adaptation has been operationalised is through 'mainstreaming' into country programmes and projects. As noted in section 3, 'mainstreaming' implies that awareness of climate impacts and measures to address these impacts are integrated into the policies, programmes and projects. Mainstreaming has been driven by CRM principles but also by the promotion of IWRM that takes into account future climate risks. An ongoing challenge is how to ensure climate change uncertainties are effectively integrated within IWRM (World Bank, 2006).

Mainstreaming at country and programme level

In developing countries, mainstreaming is in its early stages and has been led mainly through the preparation of NAPAs and other policy processes described in Section 3. A few countries have made efforts to more concertedly mainstream water-related adaptation measures at the country and programme level. Three cases – India, Honduras and Bangladesh – and their experiences are briefly considered here.

India and the National Disaster Framework

During the 1990s, India lost roughly 2.2 % of its GDP annually (approximately US\$6 billion) to disasters. Such disasters may increase in frequency and intensity as a result of climate change. In response, the Indian government developed a National Disaster Framework (NDF), which is based on integrating disaster mitigation into the development process (see Box 4.2). The NDF takes a multi-disciplinary and cross-sectoral approach to disaster management, and targets: (a) *Early Warning Systems*; (b) *Disaster Prevention*; (c) *Knowledge Management*; and, (d) *Human Resource Development*.

Box 4.2: India – the National Disaster Framework

Case study overview

During the 1990s, India lost 2.2 % of its GDP annually (approximately US\$6 billion) to disasters. Such disasters may increase in frequency and intensity as a result of climatic changes. In response, the Indian government developed a National Disaster Framework (NDF), based on integrating disaster mitigation into the development process.

Programme implementation

- Disaster management has been moved to the more powerful Ministry of Home Affairs. Implementation is supported by other actors e.g. the Indian Meteorological Department or Central Water Commission.
- National Crisis Management Committee has also been established to help coordinate implementation.
- The NDF focuses on preparedness and response with regard to: (i) Early Warning Systems and Flood Forecasting; (ii) Disaster Prevention and Mitigation; (iii) Research and Knowledge Management; and, (iv) Human Resource Development & Capacity Building.

Lessons learned

- Effective mainstreaming requires complex, multi-sectoral institutional and policy coordination.
- Adaptation needs to be prioritised in the budgetary process and be housed in a powerful Ministry.
- Capacity-building and communication activities (training, communication, education, involvement of the corporate sector, mass media campaigns and participatory planning) are indispensable.

Source: Government of India, 2004.

Honduras and flood planning

A second example of mainstreaming, focused more specifically on water resources management, is Honduras' flood planning in La Ceiba, supported by USAID's Integrated Management of Natural Resources programme. The city of La Ceiba is vulnerable to flooding, coastal erosion and coastal storms, and one element of the programme is to address the risks of climate change to coastal development, urban drainage and upstream land management.

This case illustrates the types of actors, processes and actions that are required to ensure that climate change is mainstreamed into WASH-related activities. One of the major lessons learned is that extensive stakeholder consultation plays a key role in helping to identify *feasible* and targeted adaptation solutions – in this case, an upgraded drainage system (see Box 4.3).

Box 4.3: Honduras – climate change, coastal resources and flood planning

Case Study Overview

The city of La Ceiba is vulnerable to flooding, coastal erosion and coastal storms. The city is currently involved in USAID's Integrated Management of Natural Resources programme. One element of the programme addresses the risks of climate change to coastal development, urban drainage and upstream land management.

Programme Implementation

- *Stage I: Screening* – to assess if climate change will compromise integrity or effectiveness of planned projects.
- *Stage II: Identifying Adaptation & Analysis* – identifying adaptation options through stakeholder consultations and evaluating the effectiveness, cost, and feasibility of options.
- *Stage III: Identifying Course of Action* – consulting technical experts to review the feasibility of identified adaptation options and consultations with planning authorities to select strategies; and
- *Stage IV: Developing an Implementation Plan* – developing an implementation plan consistent with USAID's mission and contracting other adaptation options to other agencies.

Lessons Learned so far

- Based on the consultations, building an enhanced urban drainage system that can cope with current and future risks of climate change was identified as a cost-effective adaptation priority.
- Stakeholder consultation was important in assessing climate change impacts and in the development of *feasible* adaptation options.
- It was useful to draw on a panel of international and national researchers to ensure 'quality control'.

Source: Stratus Consulting, 2006

Bangladesh and the Country Disaster Management Programme

A third and final case of mainstreaming can be found in Bangladesh. The Bangladeshi Government has adopted a Country Disaster Management Programme (CDMP) which aims to ensure that CC is mainstreamed at all levels and across sectors and to strengthen operational capacity to respond to emergencies and disaster situations (see Box 4.4).

Box 4.4: Bangladesh – the Country Disaster Management Programme

Case study overview

This Bangladesh case study highlights the process through which the Government has sought to mainstream climate change into development projects. The Government has developed a Country Disaster Management Programme (CDMP) which aims to ensure that climate change is mainstreamed at all levels and across sectors and to strengthen operational capacity to respond to emergencies and disaster situations.

Programme implementation

The CDMP fulfils a number of principal functions:

- It provides a framework to guide risk analysis, community risk assessment and modelling.
- It provides a framework for developing, planning, assessing and validating projects.
- It is a vehicle for implementing projects. For instance, a Local Disaster Risk Reduction Fund has been set up under the CDMP, which implements local-level projects and action plans.
- The key stakeholders involved in the CDMP process at the project level include researchers, policy makers, local communities, community-based organisations, NGOs and local government representatives.

Lessons learned so far

- Development partners, particularly DfID, the World Bank, Denmark, The Netherlands, & the European Union have found it useful to promote their assistance through the CDMP framework.
- Economic analysis under the CDMP helps develop ‘climate-resilient’ investment programmes.
- The CDMP is facilitating the mainstreaming of disaster and climate risk management into national development planning. For instance the Country PRSP now addresses climate risk.
- It was important to locate the programme in a key ministry and to ensure stakeholder participation.

Source: Climate Change Cell, 2008, Ministry of Food and Disaster Management, 2008.

This case highlights the process through which the government has sought to mainstream climate change into development projects. Also, the CDMP experience illustrates how Bangladesh has made effective steps towards integrating adaptation at the country and programme level, namely by providing a framework for assessing risk, for developing and validating projects, and for implementing and promoting risk reduction projects at the country, sector and local/community level. There is limited evidence, however, about how specific WASH-sector projects and initiatives have been developed and implemented under the CDMP.

4.5 Community-level adaptation initiatives

A key concern about current ‘screening’ and ‘mainstreaming’ is that they do not effectively incorporate the knowledge and needs of the poorest (SIWI, 2008). But exposure to climate variability and extremes poses *substantial* risks to the livelihoods of the poor and vulnerable. In terms of water resources, climate change may worsen poor people’s already-woeful access to a sufficient quantity and quality of water and potentially increase their vulnerability through prolonged droughts or increased floods, as Section 2 suggested (see UNDP, 2007/2008). Cognisant of this, a CBA approach has been promoted in policy processes at the international and national level (see Section 3). To encourage the integration of CBA at the project-level, a specialised toolkit has been developed.

Community-based climate risk screening

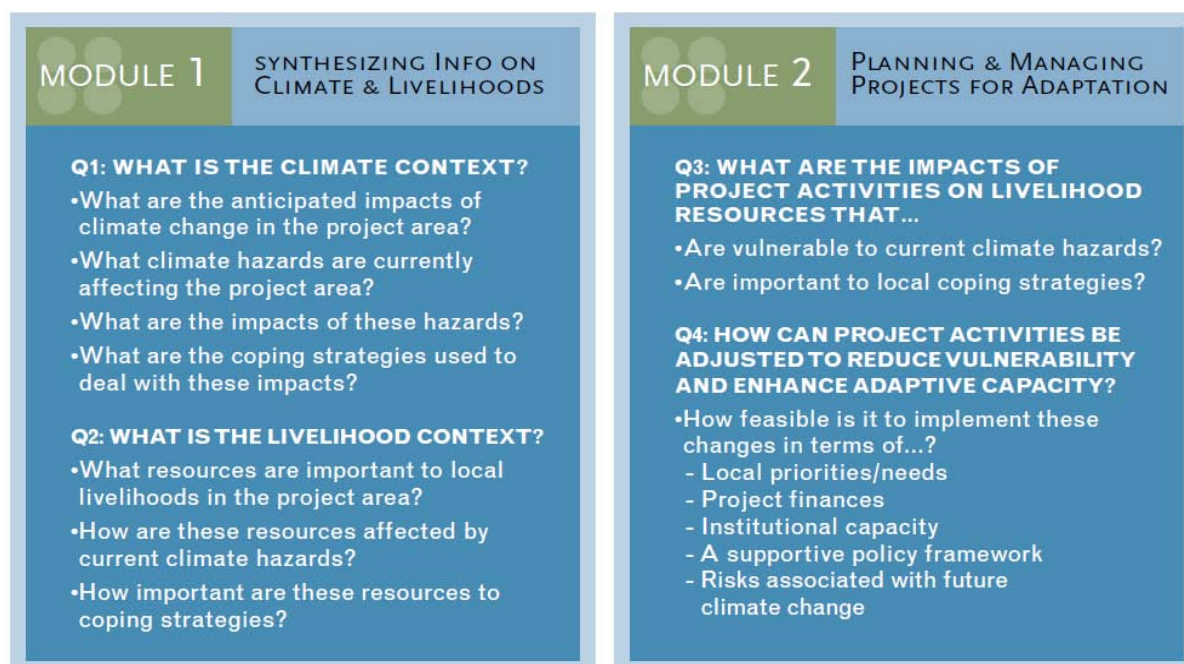
To ensure that local perspectives are incorporated into project planning, a consortium of NGOs has developed a risk screening tool called *Community-Based Risk Screening Tool – Adaptation and Livelihoods (CRiSTAL)* (IISD et al. 2009). CRiSTAL draws on the Sustainable Livelihoods Framework (SLF) because its developers found that many SL projects had increased community resilience to a range of

threats, including climate change, by securing the natural resource base, by reducing exposure to climate hazards and by diversifying livelihood activities (see also Elasha et al., 2005, Hellmuth et al. 2007).

The objective of CRiSTAL is to provide a mechanism for project managers to assess the role and impact of a project vis-à-vis climate adaptation and livelihoods. The mechanism is designed to: (a) help users to systematically understand the links between local livelihoods and climate; (b) enable users to assess how people cope, looking at the resources needed to cope with climate stress; (c) enable assessment of a project's impact on community-level adaptive capacity; and, (d) assist users in making adjustments to improve a project's impact on adaptive capacity.

To achieve its goals, the CRiSTAL method asks four framing questions divided into two modules (see Box 4.5).⁶ Data collection is conducted in a participatory manner. A participatory approach to CBA enables the poor's views to be represented, it ensures that project managers focus on feasible livelihood-related issues, it raises awareness of adaptation at the community-level, and it provides a platform for debate and consensus-building. This approach increases the probability that an adaptation initiative will be sustainable (Bie et. al, 2008; ISDR & UNDP, 2007). CRiSTAL could be applied to WASH-livelihood projects. It has been field-tested in five countries – Bangladesh, Mali, Nicaragua, Sri Lanka and Tanzania. Test results are currently being evaluated.

Box 4.5: Community-based Risk Screening Tool – Adaptation and Livelihoods (CRISTAL)



Community-level adaptation projects

Structural and non-structural responses

Alongside the development of community risk screening, a number of actors also promote a range of pro-poor adaptation projects in the WASH sector. Such projects can be *structural* or *non-structural*. For instance, the raising of hand-pumps above expected flood levels is a structural example. Awareness-raising of the risks associated with climate change is a non-structural example. However, the two methods are connected; without awareness of the flood risks, the imperative for investing in building a raised platform will be lost. As such, the most successful projects combine both structural (and technical) soundness with non-structural measures such as awareness-raising and participation (see MacDonald et al, 2005).

⁶ The latest version of CRiSTAL can be downloaded from the website: <http://www.cristaltool.org>

African cities, water and adaptation

It is worth also reflecting on some of the lessons learned from recent analysis of community-level adaptation. A useful case is provided by Action Aid who carried out a community-level analysis of coping mechanisms for flood risk management in six African cities (see Box 4.6 below). The study found that government authorities at the national and local level have done little to support community-level adaptation. For instance, in Uganda, local council leaders were failing to enforce construction and sanitation regulations; or, in Nigeria, even though disaster reduction is incorporated into the PRSP, the budget allocated to its implementation is very limited.

This absence of government support leaves communities with no other option but to develop their own 'autonomous' coping strategies, such as bailing-out or digging trenches. But such strategies, *without more support*, are not fully effective, adequate or sustainable. Action Aid thus put forward a set of recommendations, including: (a) governments must play a lead role in supporting community-level coping-strategies; (b) pro-poor participatory decision-making must be integrated into adaptation implementation; and, (c) attention must be focused on the *human* challenge of adaptive water management.

Box 4.6: Adaptation to flooding in African cities – a community perspective

Case study overview

A study was undertaken by Action Aid based on participatory vulnerability assessment with slum dwellers in six African cities – Accra, Freetown, Kampala, Lagos, Maputo and Nairobi. The study assessed community-level coping mechanisms for flood risk management. It found that planned adaptation strategies, where they do exist, often do not engage with poor communities or are not implemented, leaving poor communities with inadequate coping mechanisms.

Study findings

- Adaptation in African cities should be carried out by both local communities (autonomous) and by the government (planned). Autonomous interventions include: bailing out water from houses, placing children in safer areas, digging trenches around houses, constructing temporary dykes or trenches, securing structures with waterproof material, using sandbags to prevent ingress of water, relocating etc.
- However, government authorities at the local and national level have done little in practice to support such adaptation. For instance, in Ghana local authorities had done little to clean and maintain drains.

Study recommendations

- Governments need to play a more proactive role in supporting adaptation at the community level.
- A range of projects are needed that: (i) ensure service delivery during floods; (ii) invest in drainage infrastructure and solid waste disposal; and, (iii) enforce bye-laws on construction and sanitation.
- Policies, planning and actions should address the *human* challenge of adaptation.
- Need to promote pro-poor participatory decision-making processes in adaptation planning.

Source: Action Aid, 2006

Examples of ongoing CBA projects

Various actors are currently promoting a range of CBA projects, notably in the WASH sector. Table 4.3 provides a snapshot of the types of CBA projects and the actors involved. Taken as a whole, although many projects are still ongoing, a range of lessons have been learned (see ISDR & UNDP, 2007, UNFCCC, 2009, WRI, 2007):

- *Good 'Adaptation' Communication* – it is vital to have a good communication strategy with awareness-raising and sensitisation.
- *Build Coping Capacity* – existing coping strategies are often inadequate and need to be reinforced through training, technology and alternative livelihood options.
- *Participatory Approach* - adopting an inclusive participatory approach strengthens community responsiveness to adaptation.
- *Livelihoods* – emphasis needs to be placed on livelihood protection. Communities need to see benefits and have incentives to carry out initiatives.

- *National and Local Politics* – national and local ‘political’ and financial support has proven fundamental to the success of community-level adaptation.
- *Equity and Access* – projects need to more directly deal with questions of equity and access.

Table 4.2: Examples of community-based adaptation projects

Key Players	Role(s)	Brief Examples
Local communities	<ul style="list-style-type: none"> ▪ Drivers of adaptation strategies ▪ Repository of traditional knowledge 	<p>In Thailand, communities in the Lower Songkram River Basin are modifying their fishing gear and their rice-growing strategies to deal with climate variability.</p> <p>In Pangu in Sri Lanka, a traditional system of cooperative irrigation reservoir maintenance helps ensure water availability during droughts.</p>
Community organisations	<ul style="list-style-type: none"> ▪ Lead projects ▪ Ensure micro-credit repayments 	<p>In Kenya, community organisations are promoting the Drought Cycle Management Approach.</p> <p>In Peru, the Waru Waru Restoration project has revived an ancient canalisation technique designed to provide moisture to farms during droughts and drainage during heavy rains.</p>
Government bodies	<ul style="list-style-type: none"> ▪ Provide a regulatory framework for CBA ▪ Facilitate decentralised planning 	<p>In India, the government provides a regulatory framework for bio-fuel policy and micro-insurance.</p> <p>In Argentina, the Government has been responsible for driving the decentralised renewable energy programme, which provides rural communities with access to electricity.</p>
NGOs	<ul style="list-style-type: none"> ▪ Communicate climate risks to communities and governments ▪ Strengthen adaptation capacity 	<p>In Indonesia, SouthSouthNorth is working to bridge the knowledge gap between local and expert knowledge into a decision-making process to address climate threats.</p> <p>In Kenya, the Red Cross is training communities in flood prevention and protection. In Malawi, Tearfund is promoting small and medium-scale initiatives to control river flow.</p>
Private sector	<ul style="list-style-type: none"> ▪ Provide services ▪ Provide insurance/financial products 	<p>In India, JK paper mills and the World Bank to support a community-based carbon sequestration project.</p> <p>In Malawi, the private sector is providing index-based weather insurance schemes for small-scale farmers.</p>
Donors	<ul style="list-style-type: none"> ▪ Initiate adaptation activities 	<p>A number of donors such as the World Bank, UNDP, GEF and DfID are financing a range of CBA projects.</p>

Sources: ISDR & UNDP, 2007, UNFCCC, 2009, WRI, 2007

4.6 Monitoring and evaluation, vulnerability reduction assessment

A final yet vital element of this paper focuses on M&E. It is now generally agreed that indicators need to be developed to monitor adaptation implementation, to follow-up on project activities and to respond to changes over time. Indeed, given the uncertainty of predicting climate futures, *flexibility* is a key ingredient of robust and long-term adaptation. However, vulnerability, and its reduction, is a difficult thing to measure and the development of tools to monitor progress is in its infancy. Notably, UNDP and the GEF are developing a toolkit called the Vulnerability Reduction Assessment (VRA) that may be fit for purpose.

Vulnerability reduction assessment

The VRA is designed to measure the changing climate vulnerabilities of communities, and to be comparable across different projects, regions, and contexts, making it possible to determine if a given project is successful or unsuccessful in reducing climate risks. The VRA can be compared to a guided participatory rural appraisal, focusing on community perceptions of vulnerability to climate change and capacity to adapt. It is based on a composite of four indicator questions, posed during a series of three or four community level meetings over the period of a project. Table 4.4 gives an overview of the VRA

method, drawing on the example of drought, which is particularly relevant to the WASH sector. The VRA's perception-based approach is a compliment to quantitative indicators that are also used to measure project results.

Some lessons have been learned about the VRA from the UNDP's pilot experiences in Jamaica, Namibia, Niger and Guatemala. First, a VRA has to be targeted and must speak to the community's experiences and livelihoods. Second, the process holds the project accountable to the communities and provides ongoing information that can guide adaptive project management. Third, communities may not be immediately forthcoming with their perspectives and may reserve judgement until the project yields tangible results (Crane et al. 2008).

Table 4.3: Vulnerability Reduction Assessment (VRA) methodology

APF Step	VRA Indicator	VRA Questions	Logic
<i>Assessing current vulnerability</i>	1. Vulnerability of livelihood to existing CC and/or CV.	<i>Example: Rate the impact of drought on your livelihood.</i>	▪ Addresses present climate-related development issues – often the main climate concern of the community.
	2. Efficacy of coping mechanisms in face of current CC/CV risks.	<i>Example: Rate your community's ability to cope with negative impacts of drought.</i>	▪ During the first VRA consultation, this question will describe baseline adaptation. During subsequent consultations, it will assess progress against that baseline.
<i>Assessing future climate risks</i>	3. Vulnerability of livelihood/welfare to developing CC risks.	<i>Example: Rate the impact to your livelihood if droughts became twice as frequent.</i>	▪ Once present context of variability has been discussed, this question focuses the community on their perceptions of likely impacts of CC.
	4. Ability of the community to respond to developing CC risks.	<i>Example: Rate how your community would be able to cope with doubled drought frequency.</i>	▪ This question compliments the previous one by focusing the community on potential actions to respond to CC.
<i>Formulating an adaptation strategy</i>	5. Magnitude of barriers (institutional, policy, technological, financial, etc) barriers to adaptation.	<i>Example: Rate how effective you think this project will be in reducing your risks from increasing droughts.</i>	<ul style="list-style-type: none"> ▪ This question will qualify the above question, and focus it onto the needs of the community in successfully achieving adaptation. ▪ This question will identify policy barriers, forming useful lessons for the country and global programmes.
<i>Continuing the adaptation process</i>	6. Ability and willingness of the community to sustain the project intervention	<i>Example: Rate your confidence that the project will continue to reduce drought risks after project period.</i>	▪ This question measures project sustainability and ownership, essential if adaptation to long-term CC is to be successful.
	7. Ability and capacity of community to continue the adaptation process, and to carry it beyond the specific project focus	<i>Example: Rate your ability to cope with increasing droughts after this project is over.</i>	▪ This question measures adaptive capacity more directly than other questions, as it seeks to determine to what extent communities will continue to adapt, and to what extent they feel that they are able to do so.

Source: Crane et al. 2008

4.7 Key messages

Actors

- There are a range of actors from the international to local level, who can fulfil important, but differing, pro-poor adaptation roles and functions. However, to date, many of these roles and functions are only being partially fulfilled or are not fulfilled at all.

Toolkits and approaches

- WASH and WRM investments, programmes and projects can be screened for climate risks and levels of vulnerability using new toolkits such as ADAPT, ORCHID, WELS and Cost-Benefit Analyses. Effective screening aims to: ascertain the extent to which existing development projects already consider climate risks, identify strategies for incorporating climate change into future projects, and guide project managers to options that can minimise risks. A major challenge with such screening is to ensure that ‘its top-down’ approach is combined with ‘bottom-up’ inputs and that reliable local climate information is available.
- To promote *pro-poor* adaptation, a community-based screening tool, CRiSTAL, has been developed, drawing on a SLF. It aims to help users understand links between livelihoods and climate and to assess a project’s impact on community adaptive capacity. Potentially, this toolkit could be applied to WRM interventions, yet further analysis and field-testing is required to determine its effectiveness.
- Alternatively, existing approaches such as Water Safety Planning could be extended to include screening for climate change risks and impacts. In view of the ‘data gap’ in most developing countries, and difficulties in downscaling climate projections at the basin scale and below, scenario-based approaches which consider a range of different climate futures are recommended.

Experience

- Experiences of climate mainstreaming illustrate that: effective mainstreaming requires complex policy and institutional coordination; WASH-sector adaptation needs to be prioritised in the budgetary allocation process; and, capacity-building and consultation are key. ‘Mainstreaming’, however, usually focuses at the level of government. The extent to which the poor are represented in such processes is questionable.
- Lessons have been learned from implementing community-level adaptation projects. These lessons include: a wide-reaching communication strategy is needed; interventions should build upon *existing* coping strategies; focus should be placed on livelihoods and clear benefits should be provided to the community; national and local ‘political’ support markedly increases the probability of project sustainability; and, issues of equity, access and water resource distribution have only been patchily integrated into adaptation project design.
- A key element of adaptation is a flexible and long-term approach to M&E. Preliminary evidence from UNDP field experience suggests that its ‘VRA’ tool – designed to assess vulnerability and measure project impacts over time – may be fit for purpose.

5 Summary and key messages

This report has explored the links between climate change, water resources and water and sanitation services, with a focus on SSA and South Asia. No new (primary) research has been presented. Rather, the aim has been to review the available literature, and use expert judgement to assess the impacts of climate change on WASH.

It is important to note that although climate change and its projected impacts will present new challenges in delivering sustainable access to sanitation, there is a marked absence of literature on this topic. As such, this report has largely focused on water resources and water supply. A key conclusion of this report though is that more research is required to better understand the impacts of climate change on existing sanitation systems and to identify effective responses to current and future climate change.

5.1 Climate change predictions and uncertainties

Climate warming is now beyond doubt, with significant increases in global mean air temperature, sea surface temperature and sea level rise since 1960. Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the recorded increase in anthropogenic GHG concentrations. Continued population growth and increased global economic development is likely to increase GHG emissions further, with the result that climate change will occur at a faster rate over the next 50 years at least.

Quantitative projections of future emissions and climate change are set out by the IPCC. The IPCC scenarios, which set the scientific baseline, assign different significance to the main demographic, economic and technological driving forces of emissions for different possible pathways of global socio-economic development. Emission scenarios are run through the suite of available GCMs to generate a range of plausible outcomes in terms of temperatures, pressure and rainfall for the (nominal) years of 2030, 2070 and 2100, with calibration against historical records and observed trends. Scenarios presented in the 4th IPCC Assessment Report are now widely viewed as conservative, with present day emissions of GHGs higher than those projected by the worst case IPCC scenario, and consistent with a rise in near surface temperatures of 3-4°C and 3-5 °C over SSA and South Asia, respectively.

Although GCMs have steadily improved in performance over the last decade, major uncertainties remain. In particular, downscaling problems and difficulties in predicting land-surface – atmosphere interactions mean that rainfall is difficult to predict, particularly over continental interiors. Moreover, because uncertain climate models are being used to predict hydrological impacts and evolve adaptation strategies, the ‘chain of uncertainty’ lengthens. Nonetheless, it now seems clear that global warming will cause an intensification of present climatic and hydrological variability in Africa and South Asia. In short, wet areas will become wetter, and dry and arid areas will become more so. In addition extreme events – such as tropical storms, floods and droughts – are likely to increase in both frequency and intensity. Although climate variability is likely to increase, it is not (yet) possible to make robust projections of how much, or over what time periods.

5.2 Impacts on water resources and water-dependent services

Climate change is expected to alter hydrological regimes and patterns of freshwater availability and quality.

In terms of **water availability**, projected effects include: more seasonal and higher intensity rainfall; increasing seasonality of river flows; modification of groundwater recharge patterns; and risk of significant reduction in the volume of reliable surface water resources. In South Asia, a reduction in overall river flows of up to 20% is expected by 2100. Since many major rivers are fed by glacial meltwater, however, this overall trend masks an initial increase in river flows as glaciers melts, followed by a reduction in flows as the ice mass gets smaller. River flows in Africa are much more dependent on changes in rainfall than on temperature because of the absence of snow melt. Over large areas of SSA, uncertainties in rainfall projections make surface water ‘futures’ particularly hard to predict.

Groundwater systems respond more slowly to changes in climate, but the direction and magnitude of lagged effects is uncertain. In part this reflects the lack of data on groundwater; monitoring information on groundwater conditions is patchy or non-existent in most developing countries, and relatively little is known about available groundwater in many regions. Moreover, climate projections tell us very little about the timing, intensity and duration of rainfall events – factors that have a more significant impact on groundwater recharge than longer term trends in average rainfall.

Climate change will not change the basic nature of **threats to water supply and sanitation technologies**, but is likely to change the severity and magnitude of those threats. Extended dry periods may cause water sources to dry up, or become less reliable, and reduce the performance of sewers. Heavy rainfall events may cause damage to infrastructure, flooding and contamination of water supplies. Reductions in the reliability of rainwater harvesting schemes are likely, highlighting a greater need for and reliance on both natural and man-made water storage. Groundwater sources are generally less vulnerable to climate change, although supplies from aquifers of low storage capacity, at shallower depths, may become less reliable. However, it is important to emphasise that only limited recharge is needed to sustain groundwater-based domestic supplies.

Looking specifically at **water quality and public health**, it is likely that more intense rainfall events will result in increased turbidity of surface water as well as higher (seasonal) contaminant loading of shallow groundwater, possibly leading to an increase in water-borne disease. Increased flooding may also overwhelm currently used sanitary protection measures leading to infrastructure damage and water contamination. In coastal areas there is likely to be significant incursion of salt water into aquifers as sea-levels rise, greater flood damage to both water supply and sanitation systems in low lying, densely populated areas, and hence risks to public health.

It is important to emphasise that climate change is one of a number of pressures on water and livelihoods. In many countries, there are **multiple, inter-related pressures**, including demographic shifts, urbanisation, changing patterns and levels of consumption, and pollution - drivers of change that will affect the supply of water, the demand for water, or both. These drivers of change may pose bigger threats to future water resources and water-dependent services than climate change alone.

Climate change raises significant issues around **equity and sustainability in service provision** and access, because the biggest impacts will fall on the poorest and most vulnerable groups – those least able to cope with existing climate variability, and with low or no access to improved water supplies and sanitation. Extending access to reliable and affordable water and sanitation services for these groups (see below) therefore remains key to strengthening livelihoods *and* building resilience to climate change.

5.3 Policy responses – international, national, local

Adaptation to the impacts of current and future climate change is unavoidable, and **adaptation is now viewed as an essential component of any climate change policy**. Arguments focus on which countries need to adapt, which sectors, areas and groups of people are most vulnerable, and how best to provide support in ways that build on local knowledge and ensure long-term resilience.

At a **global level**, adaptation planning is being carried out under the UNFCCC. Planning focuses on three issue-areas: Developing a Shared Vision on Adaptation; Identifying Means to Implement Adaptation; and Enhancing Financial and Technical Support for Adaptation. Despite pressure from some stakeholders to include water in the Copenhagen negotiations, the Copenhagen Accord, signed in December 2009, makes no specific mention of water issues. However, given the intrinsic relationship between adaptation and water, many elements of the accord dealing with adaptation are of relevance to the water sector.

At a **national level**, government responses have centred on the creation of NAPAs. Programmes of Action focus on: assessing vulnerability to climate change; identifying adaptation strategies; and identifying means to implement adaptation strategies – typically project based. While the process of NAPA preparation has generally been successful in raising awareness of climate change and encouraging dialogue between different stakeholders, adaptation plans have generally not been mainstreamed into broader development policies, including poverty reduction strategies and water

resources management. Nonetheless, most NAPAs identify water as a vulnerable ‘sector’, and attach importance to water-related adaptation.

A number of approaches – including vulnerability assessments, scenario-based planning, adaptive management, mainstreaming and community and ecosystem-based management – have been developed to facilitate adaptation planning and implementation at a **local level**. Whether these offer fresh insights into vulnerability and adaptation needs, or merely recycle established development principles, is debatable. At its heart, adaptation is essentially ‘good development in a hostile climate’: this implies that a broad understanding of poverty, and the effects of existing climate variability on livelihoods and access to water, remains essential.

5.4 Operational responses – planning for climate change in service delivery

Both **WASH and water resources management investments can be ‘screened’ for climate risks** using the approaches outlined in this report, with the aim of guiding policy makers and planners towards risk-minimising options. A major challenge, however, is the gap in knowledge in terms of both observational data and in understanding how climate change will affect the hydrological cycle and water-dependent services at the temporal and spatial scales relevant to decision making. Data gaps are especially acute in the poorest (and therefore most vulnerable) countries, particularly in relation to groundwater systems and the monitoring of WASH access and use.

Lessons have been learned from implementing community-level adaptation projects. These include: the need for a wide-reaching communication strategy; the need for interventions that build on existing coping strategies; the importance of broad-based livelihood improvement and vulnerability reduction; and the importance of national and local ‘political’ support. Equity issues – the distribution of climate change costs, and the benefits arising from planned interventions - have only been patchily integrated into programme and project design thus far.

Existing planning approaches, such as **Water Safety Planning**, can be extended to include screening for climate change risks and impacts. In view of the ‘data gap’ in most developing countries and difficulties in downscaling climate projections at the basin scale and below, scenario-based approaches which consider a range of different climate futures are recommended.

Given the uncertainties surrounding the impacts of climate change on water, **planning around technology choice should be ‘robust of uncertainty’**, i.e. appropriate to a range of different rainfall and runoff conditions. This implies a greater focus on the reliability of different sources - for example siting boreholes and deeper wells in more productive aquifers, favouring development of larger springs, and the strengthening of sanitary protection measures. However, the use of more vulnerable sources, such as shallow wells, should not be ruled out completely, particularly if they form part of a suite of water supply options available for households, and communities, across seasons.

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Annex: Online resources and glossary

Climate change: online resources

Screening Toolkits and Vulnerability Assessments

The World Bank's Climate Risk Screening toolkit **ADAPT** is still under development. Further information available at: www.worldbank.org/climatechange

The community-based risk screening tool, **CRISTAL**, is available at: <http://www.cristaltool.org>

The UNDP **Vulnerability Reduction Assessment** is outlined at: www.undp-adaptation.org/projects/websites/docs/CBA_VRA_Guide_Dec_o8.pdf

A **Water Safety Plan** approach is being developed by (amongst others) AusAID. It can be used to assess how hazards impact water supply and to assess how prepared the water supply system is to cope with such hazards. Further information can be found at: http://www.ausaid.gov.au/keyaid/water_who.cfm

For guidance on conducting environmental/climate impact assessment see **UNEP Handbook**: <http://www.decisioncraft.com/energy/papers/hbccia/chapo.pdf>

Key Climate Change Information

For a range of climate-related information see the **UNFCCC** website: <http://unfccc.int/2860.php>

The UNDP **Adaptation Policy Framework** can be found at: [URL:http://www.undp.org/gef/adaptation/climate_change/APF.htm](http://www.undp.org/gef/adaptation/climate_change/APF.htm)

See the **IPCC** website for comprehensive quantitative data: <http://www.ipcc.ch/>

See also the **OECD** work on climate change at: http://www.oecd.org/departement/o,3355,en_2649_34361_1_1_1_1_1,00.html

Another useful resource is the **Stockport Environment Institute** at: <http://www.sei.se/>

Ongoing Climate Adaptation Projects

There is a large project and programme of analysis called: **Assessments of Impacts and Adaptations to Climate Change (AIACC) in Multiple Regions and Sectors**. Information available at: <http://www.aiaccproject.org/about/about.html>

The World Bank is currently leading a programme on the **Economics of Adaptation to Climate Change**. See: <http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/ENVIRONMENT/EXTCC/o,,contentMDK:21581098~pagePK:210058~piPK:210062~theSitePK:407864,00.html>

The International Development Research Centre is currently running project entitled: **Climate Change Adaptation in Africa (CCAA) research and capacity development program**. The project aims to improve the capacity of African countries to adapt to climate change in ways that benefit the most vulnerable. Further information at: http://www.idrc.ca/en/ev-94424-201-1-DO_TOPIC.html

UNEP has an ongoing range of projects and publications on climate change. See: <http://www.unep.org/themes/climatechange/Resources/publications.asp>

Climate change: A glossary of key terms

Adaptation: adjustment in natural or human systems to a new or changing environment. Adaptation to climate change refers to adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive, private and public, and autonomous and planned (see below).

Adaptation (Anticipatory): adaptation that takes place before the impacts of climate change are observed. Also referred to as proactive adaptation.

Adaptation (Autonomous): adaptation that does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and by market or welfare changes in human systems. Also referred to as spontaneous adaptation.

Adaptation (Planned): adaptation that is the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state.

Adaptation (Private): adaptation that is initiated and implemented by individuals, households or private companies. Private adaptation is usually in the actor's rational self-interest.

Adaptation (Public): adaptation that is initiated and implemented by governments at all levels. Public adaptation is usually directed at collective needs.

Adaptation (Reactive): adaptation that takes place after impacts of climate change have been observed.

Adaptive-capacity approach: this starts with an assessment of current adaptive capacity and aims to increase this capacity to enable systems to better cope with climate change and variability.

Adaptive management: this involves the increased use of management measures that are robust enough to withstand uncertainty. Monitoring and evaluation will play a key role in adaptive management.

Anthropogenic: made by people or resulting from human activities. Usually used in the context of emissions produced as a result of human activities.

Carbon cycle: all parts (reservoirs) and fluxes of carbon. The cycle is usually thought of as four main reservoirs of carbon interconnected by pathways of exchange. The reservoirs are the atmosphere, terrestrial biosphere (usually includes freshwater systems), oceans, and sediments (includes fossil fuels). The annual movements of carbon, the carbon exchanges between reservoirs, occur because of various chemical, physical, geological, and biological processes. The ocean contains the largest pool of carbon near the surface of the Earth, but most of that pool is not involved with rapid exchange with the atmosphere.

Climate change: climate change refers to any significant change in measures of climate (such as temperature, precipitation, or wind) lasting for an extended period (decades or longer). Climate change may result from: natural factors, such as changes in the sun's intensity or slow changes in the Earth's orbit around the sun; natural processes within the climate system (e.g. changes in ocean circulation); and, human activities that change the atmosphere's composition (e.g. through burning fossil fuels) and the land surface (e.g. deforestation, reforestation, urbanization, desertification, etc.).

Climate feedback: an interaction mechanism between processes in the climate system is called a climate feedback, when the result of an initial process triggers changes in a second process that in turn influences the initial one. A positive feedback intensifies the original process, and a negative feedback reduces it.

Climate mainstreaming: implies that awareness of climate impacts and associated measures to address these impacts are integrated into existing and future policies and plans of developing countries, as well as multilateral institutions, donor agencies and NGOs.

Climate model: a quantitative way of representing the interactions of the atmosphere, oceans, land surface, and ice. Models can range from relatively simple to quite comprehensive.

Climate Risk Management (CRM): this is a broad approach to climate-sensitive decision making that is increasingly seen as the way forward in dealing with climate variability and change. In simple terms, it seeks to promote sustainable development by reducing the vulnerability associated with climate risk.

Climate screening: this is a process-based approach that could be applied to WASH sector investments. If used effectively, screening aims to: (i) raise the profile of adaptation to climate change in project planning; (ii) ascertain the extent to which existing development projects already consider climate risks or address vulnerability to climate variability and change; (iii) reduce the risk of 'underperformance' of investments and guide project managers to options that minimise risks; and (iv) identify opportunities and strategies for incorporating climate change into future projects.

Community-based adaptation: this is a bottom-up and 'place-based' approach to adaptation. It begins by identifying areas and communities that are most vulnerable to climate risk, and then uses the best available science on climate induced impacts to engage with them.

Demand-side adaptation: demand side options focus on saving water and re-allocation between users and uses to increase 'value' or 'output' per drop.

Ecosystem-based adaptation: this is based on the premise that well managed ecosystems support adaptation by increasing the resilience and decreasing vulnerability of people and their livelihoods to the impacts of climate. Ecosystem-based adaptation is compatible with a number of other adaptation approaches, like community-based adaptation, disaster risk reduction and sustainable water management.

Forcing mechanism: a process that alters the energy balance of the climate system, i.e. changes the relative balance between incoming solar radiation and outgoing infrared radiation from Earth. Such mechanisms include changes in solar irradiance, volcanic eruptions, and enhancement of the natural greenhouse effect by emissions of greenhouse gases.

Greenhouse gas: any gas that absorbs infrared radiation in the atmosphere. Greenhouse gases include, but are not limited to, water vapor, carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), ozone (O₃), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF₆).

Hazards-based approach: which aims to reduce climate induced risks (e.g. drought, flooding etc.). This approach assesses the current risk to which a system is exposed and then uses climate scenarios to estimate future vulnerability.

Hydrologic cycle: the process of evaporation, vertical and horizontal transport of vapor, condensation, precipitation, and the flow of water from continents to oceans. It is a major factor in determining climate through its influence on surface vegetation, the clouds, snow and ice, and soil moisture. The hydrologic cycle is responsible for 25 – 30% of the mid-latitudes' heat transport from the equatorial to polar regions.

Integrated Water Resource Management (IWRM): this could play an important role in facilitating effective climate mainstreaming. The IWRM approach has many elements, which include: taking on board diverse stakeholders, reshaping planning processes, coordinating land and water resources management, recognising water quantity and quality linkages, recognising conjunctive use of surface water and groundwater, and protecting and restoring natural systems. IWRM can ensure inclusive decision-making and resolve conflicts between competing water uses and, therefore, might facilitate adaptation in the water sector. However, in order to address climate impacts, IWRM will need to

consider the different types of uncertainties in the management process and the hydrological system itself.

Mal-adaptation: any changes in natural or human systems that inadvertently increase vulnerability to climatic stimuli; an adaptation that does not succeed in reducing vulnerability but increases it instead.

Mitigation: technological change and substitution that reduce resource inputs and emissions per unit of output. Although several social, economic and technological policies would produce an emission reduction, with respect to climate change, mitigation means implementing policies to reduce GHG emissions and enhance sinks. Mitigation implies the human measures, structural and non-structural, undertaken to limit the adverse impacts of climate change by reducing the levels of GHGs in the atmosphere. This is accomplished through the development of appropriate technology for reducing emissions and/or capturing them at their source.

‘No Regrets’ approach: to help plan with the high level of uncertainty surrounding climate change, a “no regrets” principle is useful. This involves taking climate-related action that makes sense in development terms anyway, *whether or not* a specific climate threat actually materialises in future.

Scenario-Based Adaptation Planning: this approach is designed to develop plausible future storylines to facilitate decision making in the context of uncertainty. Scenario development is based on a set of assumptions of the key relationships and driving forces of change. These include predictable and unpredictable features of changes in climate, the environment and socio-economic factors.


Supply-Side Adaptation: Supply side adaptation options involve increasing storage capacity or abstraction from water courses.

Vulnerability: is the degree to which a system is susceptible to, and unable to cope with, the adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate change and the variation to which a system is exposed, its sensitivity and its adaptive capacity.

Vulnerability assessments: these assess how exposed the concerned system is to CC; how sensitive the system is to this exposure; and, to what extent can the system adapt to climate induced impacts.

Vulnerability-based approach: aims to ensure that critical thresholds of vulnerability in socio-ecological systems are not exceeded under climate change. Vulnerability assessment takes into account both development conditions and sensitivity to climate change.

Vulnerability Reduction Assessment: designed to aid the long-term monitoring and evaluation of adaptation programmes and projects. Specifically, to measure the changing climate vulnerabilities of communities over time, and to be comparable across different projects, regions, and contexts, making it possible to determine if a given project is successful or unsuccessful in reducing climate change risks.



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